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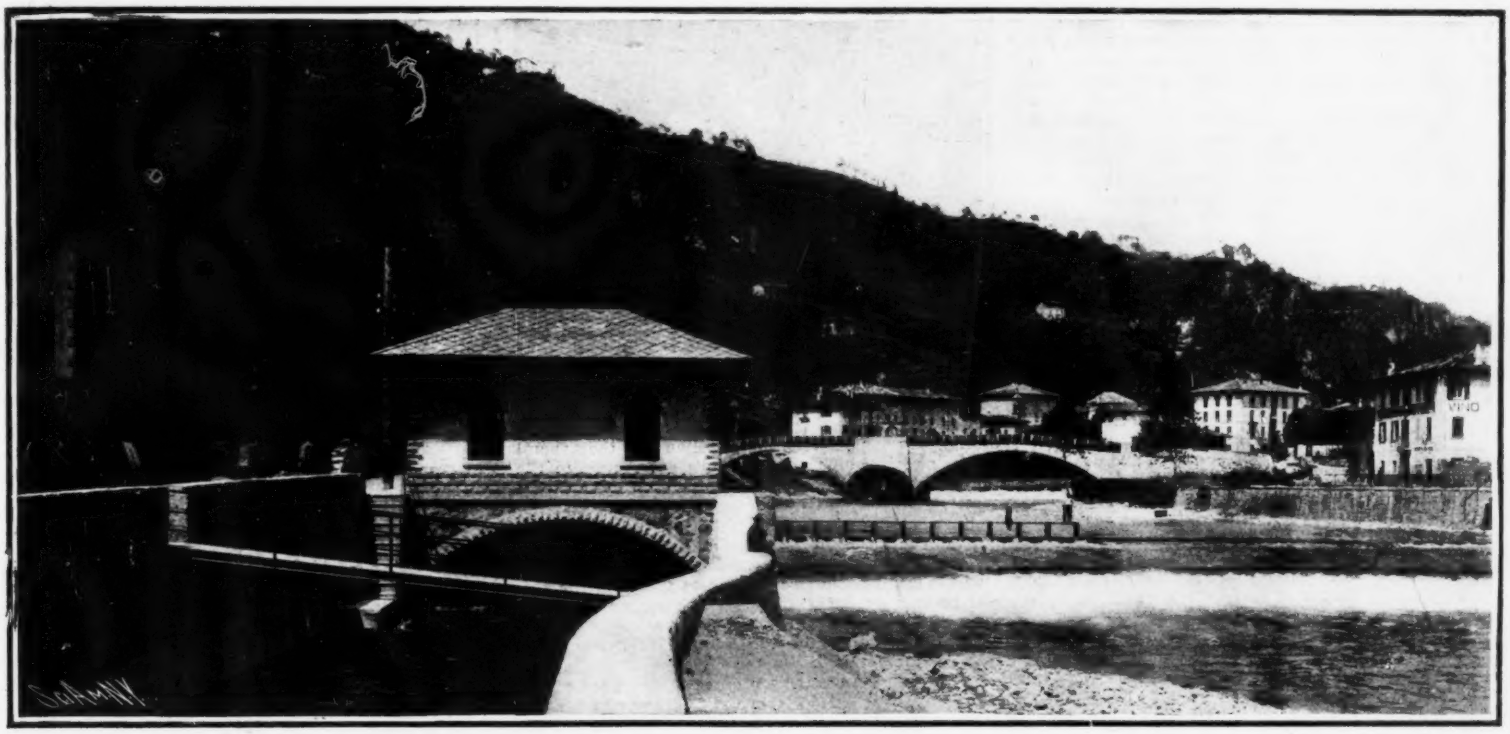


INTAKE HOUSE AND SLUICEWAY.

VIEW OF THE SLUICEWAY.

THE HYDRO-ELECTRIC POWER PLANT OF THE BREMBO RIVER.

THE HYDRO-ELECTRIC POWER PLANT OF THE BREMBO RIVER.*

By Dr. Alfred Gradenwitz.

An interesting power-transmission plant, utilizing the water power of the Brembo River, has been recently completed in northern Italy by the Società Anonima per Imprese Elettriche Conti. This river, rising in the Orobian Alps, has a hydrographical basin above the point where the power canal branches off, about 495 square kilometers in area. The available output is fairly constant, owing mainly to the many springs and lakes drained by the stream. A minimum flow is observed in the winter and in the months of July and August, though these minima are, however, very short in duration, and do not occur every year.

The available head of 55 meters is utilized for the operation of four turbo-dynamo units of 2,000 horsepower each, of which one serves as a reserve. The whole of the energy is transmitted at very high tension to the Monza district, being distributed throughout the Brianza country, reaching northward as far as the Lecco-Erba power-transmission system, and touching to the south the transmission lines of the Milan Società Edison.

The turbines were constructed by Riva Monneret & Co., of Milan, and are of the Francis type with regulation by an hydraulical servomotor. They are directly coupled with rigid sleeves to alternators built by Gadda & Co., Brioschi, Finsi & Co., likewise of Milan. These firms were also intrusted with the design and supply of the distribution system and with the operation of the central station. The main building of the central station includes a large hall, where the generator sets, and two separate sets for the excitation of the alternator fields are installed. Near this on the front side but separated from the generator room by the switchboard plant, is the room set apart for the step-up transformers.

The alternators have a speed of 350 revolutions per minute and generate current with a frequency of 42. They are of the fixed armature type producing current at the relatively low tension of 2,750 volts, and do away with the necessity of heavy insulation of the armature windings. The type chosen is the open-gap armature type with separately wound coils which are insulated throughout the length. This type has the advantage of more readily allowing the bobbins to be wound up on ready-made patterns, while special care can be bestowed on the insulation at every point, and the resistance tested before the dynamo is put in operation. The windings have thus, even in the most readily accessible outer points, an insulation as effective as those with lamellæ block contact. In the event of a coil being disabled, it is readily exchanged even by non-skilled workmen.

In constructing the conductors special care had to be taken to obviate the danger from excessive centrifugal force. The whole of the magnetic circuit had therefore to be laminated within, thus constituting a homogeneous ring of high mechanical strength. The protruding poles carry boxes of copper sheets wound spirally and held in position by bronze pieces bridging the spaces between the poles. The automatically lubricating bearings are also water cooled.

The switchboard of the power plant is especially noteworthy, owing to the novel features of its construction. A first set of reinforced concrete panels includes all the apparatus—bus-bars and conductors for 2,750 volts. Another set of panels includes the instruments and connections for 25,000 volts. Both of these sets are situated on the same floor of the building, the former facing the generator room and the other facing the transformer hall. The controlling board, whence the generator room on one hand and the transformer hall on the other are controlled, is installed underneath, being supported by a substantial iron structure. This is formed by two cast-iron panels, the central panel containing the amperemeters of the line and the general voltmeter, while four other panels correspond to the four generators respectively, and the last two to the respective sets of the transformers. Behind this controlling board are installed six cast-iron columns carrying the controlling apparatus for the 25,000 interrupters. At one end of the controlling switchboard is situated the exciter switchboard, and at the other the general registering wattmeter. No high-tension conductor reaches the switchboard, all the measuring and safety apparatus working through convenient current and tension transformers.

THE TRANSMISSION LINES.

As regards the conductors, three lead-covered cables, one for each pole, lead from the alternator to the corresponding panel. Two cables traverse two current transformers (for the maximum relay) and another, an ampèremeter transformer. Higher up, the conductor for the tension transformer branches off, thus reaching the tripolar automatical oil interrupter and the ring of the bus-bars. All the conductors of the alternators take the same course, while those leading from the bus-bars to the 1,800 K. V. A. transformers follow the same path in an opposite direction.

The time relays applied to all the automatic interrupters of the central station are worthy of notice. As is well known, the interrupters should not work instantaneously, especially in power stations, when the current assumes a given value, lest overloads of very short duration be produced, disabling the machine. The retarding effect is obtained rather simply by means of a small safety fuse arrangement, in parallel with the electro-magnets of the relay, the latter working only after burning out the fuse. This simple arrangement avoids the expensive and complicated mechanism by means of which other constructors have tried to solve the same problem.

The current generated at a pressure of 2,750 volts is raised by means of step-up transformers to 25,000 volts, at which the transmission is effected. Each three-phase transformer set consists of three 600 K. V. A. single-phase transformers, in which the outer magnetic circuit protects the winding, which is mounted on the central core and formed by vertically arranged alternating bobbins. They are of the forced ventilation type, special ventilating fans being coupled to electromotors. The air, which is led in by special channels, enters the body of the transformer, from below, passing over the coils throughout their surface, after which it escapes at the top. This type has been adopted by the Conti firm for high tensions and large units, insuring as it does great mechanical strength and better utilization of the ventilation.

The twelve single-phase transformers are located on a cement foundation behind the high-tension panels. The connections, which are well protected, are thus reduced to a minimum. The high-tension lines starting from the four units are connected through interrupters with a system of bus-bars, from which the two feeder-lines branch off. By this arrangement of the connections and channels all visible conductors and connections have been eliminated from the transformer hall, which is thus quite free and safe in spite of the very high tension.

A special lightning arrester room, including Gola, Siemens, and Wurtz dischargers, has been installed on the upper floor, the various dischargers being separated by cement partitions.

THE TURBINES AND ALTERNATORS.

THE HYDRO-ELECTRIC POWER PLANT OF THE BREMBO RIVER.

* Specially prepared for the Scientific American Supplement.

[Concluded from Supplement No. 1564, page 25059.]

REINFORCED CONCRETE CONSTRUCTION.*

By Lewis A. Hicks, Mem. Tech. Soc. Pac. Coast.

The experimental work of Prof. Talbot and Prof. Turneaure has furnished evidence that the position of the neutral axis in a reinforced concrete beam when stressed to its ultimate value approximates closely to a distance of 0.6 of the depth of the beam above the center of gravity of the steel reinforcement. Prof. Talbot has given an empirical expression for the position of the neutral axis, based on experiment, as a ratio of the depth of the beam below the compression face, viz:

$$k = 0.26 + 18p$$

This expression may be used for final determination on exceptionally important designs, but for usual percentage of reinforcement, and within allowed working stresses, it is probable that the error introduced in assuming its position at $0.4d$ below the compression face will be of much less relative importance in the result than a mistaken selection of a value for the modulus of elasticity not conformable to the actual conditions obtained in construction, and preliminary computations are much simpler by regarding its position constant.

The area of the diagram of compression stresses above the neutral axis representing the product of the maximum fiber stress and its distance from the neutral axis to the upper compressive face will vary from one-half to two-thirds of the rectangle within which its boundary line of ordinates representing fiber stress is described, and the center of application of the sum of the compressive stresses will be above the neutral axis from five-eighths to two-thirds the distance from said axis to the upper compression face. For practical designing the position of the centroid of compression is assumed to be above the neutral axis, a distance of 0.66 of the total distance to the compression face. Adopting the following notation, viz:

Let b = width of beam,
d = depth of beam from center of gravity of steel reinforcement to upper compression face,
p = ratio between sectional area of steel and concrete,
Cw = working stress in concrete,
Sw = working stress in steel,
As = area of steel,
M = bending moment in beam.

Consider a reinforced concrete beam of unit width. Since the sum of the forces on either side of the neutral axis must be equal, and since $As = p \times d \times l$, we may write, neglecting tension in the concrete,

(1) $Cw \times 0.4d \times 0.666 = Sw \times pd$, or $p = 0.26\ Cw/Sw$.

It will be observed that for given working values of safe stress in the concrete and steel there is but one percentage of reinforcement which will preserve an economic balance. It is desirable that the concrete should not be stressed in compression to more than one-fourth of its ultimate, while there is no reason why the steel, if adequate provision for adhesion is made, should not carry the same unit stresses allowed for similar grades of material in structural steel work.

It therefore appears more rational to develop formulæ in which actual allowed unit stress values may be inserted, rather than to calculate ultimate strength of the combined material and affect the result by a factor of safety common to both.

If loading permits less steel than the economic percentage in a beam of given dimensions, the compression in the concrete may be neglected, since the safe loading of the steel will not develop its safe stress. If,

* A paper read before the Electrical Transmission Section of the Pacific Coast Engineering Congress, held at the "American Inn" under the auspices of the Lewis and Clark Centennial Exposition, Portland, Ore.

on the other hand, more steel is required than indicated by the economic percentage, some provision other than the concrete itself will be required to keep the stress in the concrete within its assigned limits. If values adopted in the ordinances of some of our American cities are used in design, viz:

Safe compression value for concrete, 500 pounds per square inch.

Safe tensile value for steel, 16,000 pounds per square inch and a good grade of concrete, mixed 1-1-2-4, is used, in conjunction with commercial bars and rounds of soft steel having an elastic limit of 33,000 to 40,000 pounds, it is evident that failure will occur in the tension side long before the ultimate compressive value of the concrete is reached. Most of the experimental results confirm this, failure usually occurring from an extension of the first visible crack in the tension side of the beam, which takes place at about two-thirds of the ultimate load sustained.

The elastic limit of such bars of commercial steel as have come under the personal observation of the writer has ranged from 36,000 to 44,000 pounds, and for the working stress of 16,000 gives an average safety factor of two and one-half in steel.

If the mixture of concrete is modified to give an ultimate thirty-day crushing value of 2,400 pounds, and one-third of this adopted as working stress for concrete, there will be a more nearly balanced condition, and the economic percentage will be

$$p = 0.26\ 800/16000 = 0.0125$$

in place of about 0.008 per cent called for by limiting the stress in the concrete to 500 pounds per square inch.

The most economical method of increasing the strength of a beam of given sectional area is evidently to enrich the concrete mixture, as this not only permits higher working stresses in compression, but within working limits has a favorable influence on the condition of the concrete below the neutral axis.

The effect of placing steel on the compression side of a beam is not well determined, but some experimenters have reported that no increase of strength is obtained by such disposition of metal. The writer believes that the reason for this is the same previously noted in connection with the use of vertical bars in columns without hooping, viz: that longitudinal shearing takes place before the bars develop their compressive strength. If this is correct, the remedy would be the use of stirrups at much more frequent intervals than is usually customary.

This problem of obtaining maximum strength from members of limited depths is a constantly recurring one in building design, and although reinforced concrete girders are being constructed with steel in the compression side under moments which indicate that the steel must be supplementing the concrete, the writer would not place reliance on steel so placed without further experimental knowledge. It seems probable also that Considere's results with hooping of columns may be applied to beams with good results.

Illustrating the comparative weakness of reinforced beams, it may be stated that the modulus of rupture for pine beams for center breaking loads is 500 bd^2/L, while the same quantity for concrete beams, reinforced with 1.25 per cent of high steel having an elastic limit of 60,000 pounds, would be about 200 bd^2/L. Or, in other words, the strength of pine beams is from two to four times greater than for reinforced concrete of the same depths and spans.

This phase of design needs further investigation before special conditions existing on high building work can be successfully met.

Since the limiting conditions of allowed compressive stress are included in the determination of value of p from equation (1), we may not obtain an expression for the depth in terms of the known bending moment and allowed steel stress.

The tension in the steel is evidently equal to the quotient raising from the division of the bending moment by the lever arm of the resistance moment of the beam.

This lever arm common to both the forces above and below the neutral axis will be the sum of the distances from the neutral axis to the center of gravity of the acting forces in the steel and concrete, or

$$6d + (4d \times 5/8) = 0.85d.$$

We may now equate the forces acting below the neutral axis as found in equation (1) with this expression for tension in the steel and solve for d as follows:

$$(2)\ Sw\,pd = M/0.85d \text{ and}$$

for beams of any width this may be written

$$(3)\ d = \sqrt{\frac{0.85\,Swp}{M}}$$

$$(4)\ M = (0.85\,Sw\,p.)\,bd^2$$

a general equation which may be used for any possible safe or ultimate stress in either concrete or steel, for any percentage whatever of reinforcement. The terms 0.85 Sw will give results agreeing closely with experiment between the limits of ½ to 1 to ¾ per cent of reinforcement when the elastic limit of the steel is used in place of the working stress. Outside these limits the variation in position of neutral axis and resulting changes in length of lever arm about the center of gravity of the compressive forces necessitate more precise determination of these factors, although the continued use of the constant 0.85 will not involve errors of more than 10 per cent in excess for 2 per cent reinforcement, and above 6 per cent in deficiency for 0.001 per cent reinforcement.

Using Talbot's experiments, the relation expressing the variation in length of lever arm under changing conditions of reinforcement may be derived as follows:

$$r = \text{Lever arm} = 0.90 - 6.5p$$

and this resulting value may be substituted in equation (4) in place of the term 0.85, which is evidently correct for a reinforcement of about 1 per cent.

European engineers have derived a formula for strength of concrete beams in the form

$$M = \mu\,bd^2$$

and many foreign experiments have been tabulated in the form

$$\mu = M/bd^2$$

which furnishes a convenient comparison of the relative strength developed by different beams tested. Such tabulations have no value, however, when the characteristics of the materials are lacking. It will be observed that the formula offered by the writer can be written in the same form, and yet furnishes an analytical working conception of the results of changing percentage of reinforcement.

In this country, T. L. Condron has derived a straight line formula from the Talbot and Howe experiments, and Prof. Hatt has recently published a similar formula expressing the average results obtained from work at Purdue University. The following table gives the comparative results obtained from the Condron and Hatt formulæ for the value of the expression M/bd^2, together with those from equation (4).

TABLE I.

Reinforcement percentage	.001	.003	.005	.010	.015	.020
Hatt $102+260\,p$	129	183	237	372	507	642
Condron $55+275\,p$	82	133	193	330	467	605
(4) Hicks $0.85\,Sw\,p$	31	94	157	315	472	629
(5) Hicks $r\,Sw\,p$	33	98	161	311	444	570

The last line is computed with the corrected value of length of lever arm, r, for each percentage, and shows the influence of the lowering of the neutral axis with increased areas of metal in the beams.

For reinforcement of 1 per cent and upward the results of equation (5) $m = (r\,Sw\,p)\,bd^2$ conform more closely to the Talbot experiments than the straight line formulæ, but for the smaller reinforcements the writer is unable to offer any rational explanation for divergence in results.

The first term of the straight line formulæ is defended by the fact that in plotting the experimental values of M/bd^2 the results from bars of widely differing elastic characteristics appear to intersect the line of zero reinforcement at a common point above the base, and this point approximates the coefficient expressing the strength of a plain concrete beam.

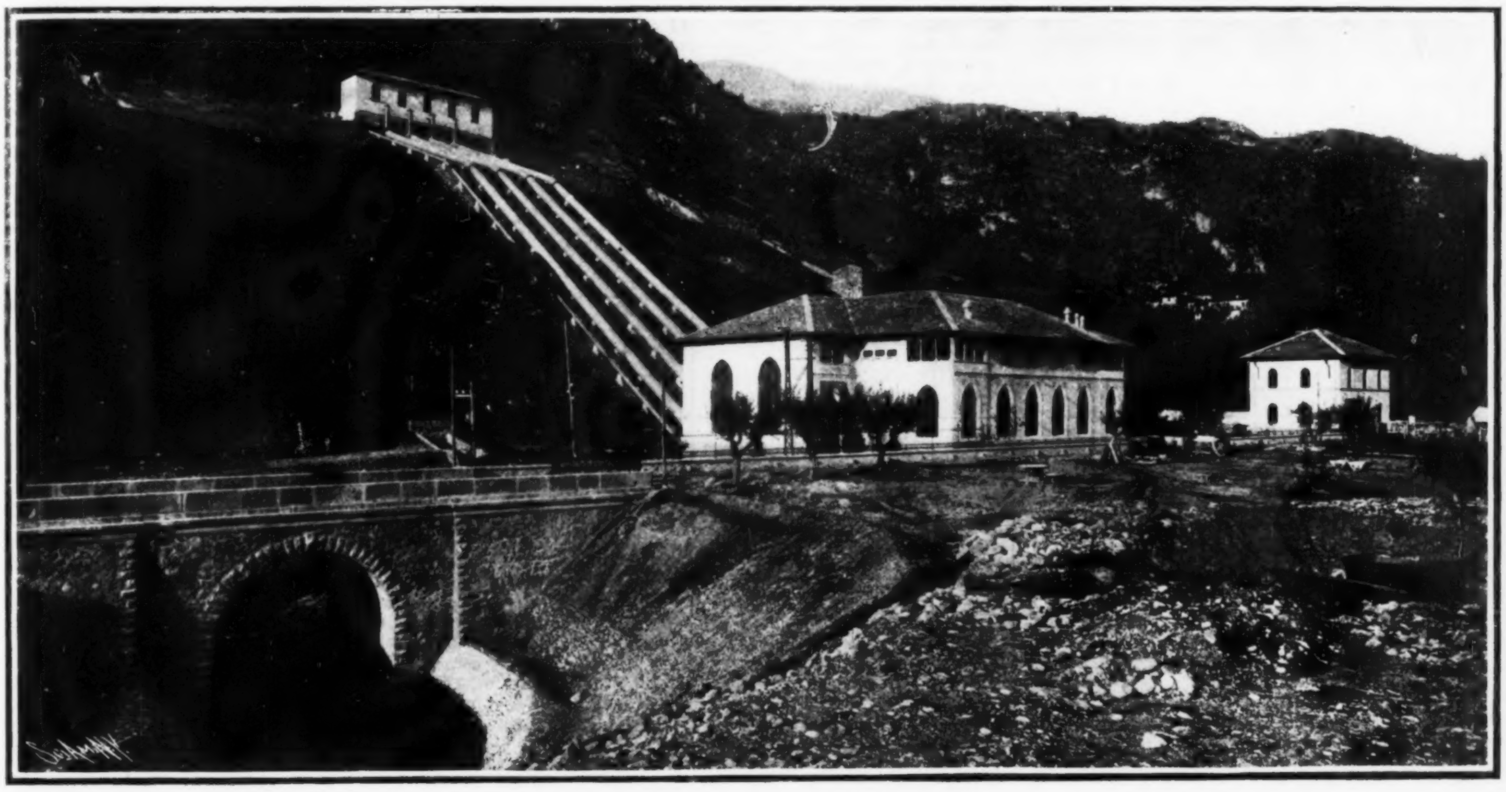
If tensile strength in the concrete is neglected, as it should be for ultimate values, it hardly seems proper to use such a term. On the other hand, if equation (5) is plotted it will be found to be a curve originating at zero values and approximating rapidly to a straight line up to 1 to ½ per cent reinforcement, where it commences to sag below the straight line, reflecting the observed facts of experiment in this respect. It is probable that it would be impossible to determine experimentally sufficiently precise values of M/bd^2 for very small ratios of reinforcement to definitely locate the curve near its lower extremity. Nor is it of any great importance to do so, since thermal considerations and the distribution of local defects in the concrete suggest the use of more steel in any beam section than would be indicated by these extremely small percentages.

The reverse is, however, true at the other end of the curve, where, if a straight line formula is used by persons unfamiliar with its derivation, there is certainty of introducing dangerous values by extending its application beyond the range intended by its authors, while the formula suggested in the form of equation (5) is shown to give results which agree as closely with experiment below 1 to ½ per cent reinforcement as the straight line formula, and above that point separates from it and continues in agreement with experiment.

The simple equation proposed, when modified to conform to change in loading, may be adapted in the usual manner to all the bending problems which arise in practice. This ground has been so thoroughly covered in numerous books and professional papers that it would be a waste of time to incorporate such matter here.

The writer merely wishes to call attention to the question of inclosure, which properly falls into the category of "bending."

In cage construction the existence of wall girders



GENERAL VIEW OF THE STATION.

THE HYDRO-ELECTRIC POWER PLANT OF THE BREMBO RIVER.

and columns furnishes ideal conditions for the use of light reinforced concrete curtain wall tied in all directions into the skeleton frame. The maximum wind loads, for the spans which occur, are insignificant compared to floor loads, and the saving in weight is important.

Front elevations and other walls receiving architectural treatment may be faced with any building material now in use, with a much more thorough bonding than is now considered necessary for a pressed brick front.

It is possible to lay up the facing, tied with wire to a back form to insure alignment, and back up with reinforced concrete as rapidly as the brickwork progresses, in such a way that the resulting combination, while saving weight and space, is much better adapted to resist the bending moment of architectural projections than ordinary brick inclosure.

All exterior walls should receive the same treatment as to damp roofing or furring required by other masonry walls.

The most important factor in the compressive strength of concrete is the void space of the sand used, since this determines the amount of cement required for unit volumes of mortar of equal strength. If the voids of all materials entering into the composition of concrete, smaller than some agreed limit, such as 1-16 inch maximum dimensions, were always measured and stated, the value of comparative tests would be greatly increased. Without this information it may often happen that a nominal 1-3-6 mixture may show greater strength than a 1-2-5 composition. Suppose the first to be made up of Niles sand with a void space of 30 per cent indicating the presence of more than sufficient cement to fill the voids, a condition requisite for the best results, and that the resulting volume of mortar is mixed with crushed rock having voids of 45 per cent indicating rather fine sizes. Again there is an excess of mortar—a condition which facilitates handling and workmanship.

Suppose the second mixture to be composed of beach sand, having a fine, uniform grain and void space of 58 per cent showing a deficiency of 16 per cent in amount of cement required to fill the voids, and a total deficiency in comparative strength of 28 per cent. There is a further deficiency in the amount of mortar present to fill the 45 per cent of voids in the rock used with both mixtures, and a probable net loss of strength, to the extent of 30 per cent in ultimate compression values when compared with mixture No. 1. Nor does this represent the worst aspect of the case.

Mixture No. 1 would produce about seven cubic feet of tamped concrete in the wall for each foot of cement used, while No. 2 would not make more than five cubic feet.

At present prices of cement in California this would mean that a cubic foot of 1-2-5 mixture would cost 3 cents more, or about 12 per cent in excess more, than for the 1-3-6 mixture, although its virtual value relatively would only be 60 per cent.

Furthermore, since design is based on the application of safety factors to ultimate values obtained from test specimens, it is apparent that the discrepancies in results obtained from lean and rich mixtures by different observers, and the low values shown by numerically rich mixtures with bad void relations, tend to the adoption of low working values, and thus bring about the use of larger quantities than would be required for the duty assigned it, if the real strength was within the knowledge of the designer.

Formulæ have been proposed for the ultimate compressive strength of concrete of differing makeup of aggregate in which neat strength of cement is the maximum to be reduced by a constant multiplied into the ratio between volume of cement and aggregate, as follows:

$C = 4500 - 250f$, where f represents the volume of aggregate divided by the volume of cement.

Applying it to the cases already noticed, ultimate values are obtained as follows:

$$\text{Mixtures}\ldots\ldots\ldots\ldots\ldots \begin{cases} \text{No. 1—1-3-6} = 2250 \\ \text{No. 2—1-2-5} = 2750 \end{cases}$$

The expression $4500-6000\,V$, where V equals the percentage of void space in the sand used smaller than 1-16-inch diameter, applies in making comparisons between mixtures having the same makeup in terms of quantities but a different void space in the sand used. The writer believes this to be the logical form for such an expression, and finds that it covers a limited range of experience in our own work with California sands.

We have tested all the sands and quarry products within freight limits of San Francisco, and find that while quarry products show a marked similarity for the same grades, there is a wide variation in the characteristics of sand and gravels.

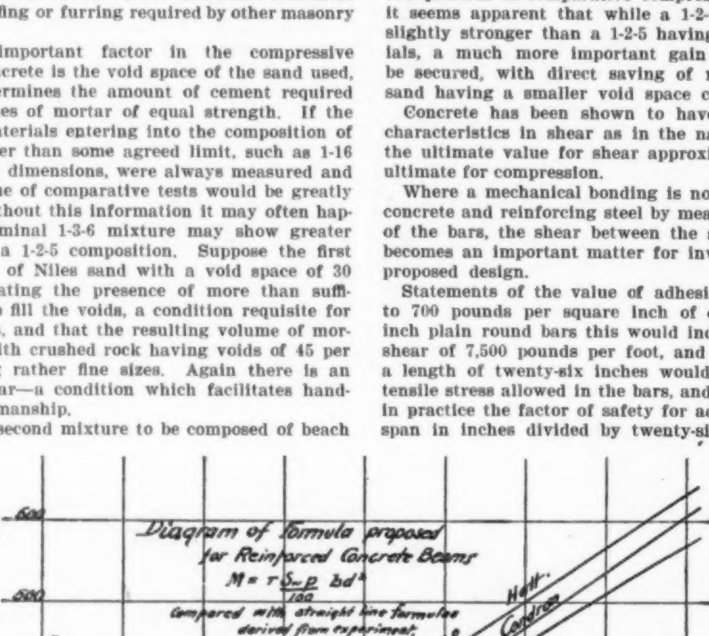
Good results can sometimes be secured by blending sands from different localities, as the resulting void space of the combination is not always the average of the sands considered separately.

There should be an authoritative determination of the question of comparative compressive strength, and it seems apparent that while a 1-2-4 mixture will be slightly stronger than a 1-2-5 having the same materials, a much more important gain in strength may be secured, with direct saving of money, if another sand having a smaller void space can be substituted.

Concrete has been shown to have about the same characteristics in shear as in the natural stones, and the ultimate value for shear approximates 1-10 of the ultimate for compression.

Where a mechanical bonding is not secured between concrete and reinforcing steel by means of deformation of the bars, the shear between the steel and concrete becomes an important matter for investigation in any proposed design.

Statements of the value of adhesion vary from 200 to 700 pounds per square inch of contact. For one inch plain round bars this would indicate a minimum shear of 7,500 pounds per foot, and would mean that a length of twenty-six inches would develop the safe tensile stress allowed in the bars, and for lengths usual in practice the factor of safety for adhesion will equal span in inches divided by twenty-six.



Inasmuch as the strength of bars of smaller size decreases as the square of the diameter while the shear decreases only as the diameter, it is evident that the smaller bars involve larger factors of safety and a better distribution of stress.

In buildings where the height or value of floor space does not limit the space available for columns, reinforced concrete may be used economically in place of steel in combination with girders and beams of the same material within such limits as the available depths and allowable compressive strains in the richest concrete mixtures used permit.

For extreme cases of concentrated loads in long spans of limited depth it is probable that resort must be had to light structural shapes of steel in both tension and compression to insure positive connection between the acting forces, independent of the concrete, except as to the useful function it still performs as a buckling or stiffening element.

Further investigation as to the design of both beams and columns is desirable before the material can be rated as acceptable in all cases.

THE SIMPLON TUNNEL.

THE Simplon tunnel, intended ultimately to pierce the Alps between Switzerland and Italy, is the longest of the great Alpine tunnels. When completed, it will have a total length of about 12¼ miles, as against 9¼ miles for the St. Gothard, and 8 miles for the Mont Cenis. It is distinguished from the other tunnels in the Alps by the fact that there are really two parallel tunnels, 55 foot centers. Each tunnel will accommodate one track. The bore is straight, with the exception of an angle at either end, due at the north to the proximity of the River Rhone at the town of Brigue, and at the southern extremity to the adjacent Divernia, just below the town of Iselle.

The track at the north portal is about 2,250 feet above sea-level. From this point the tunnel rises with a 2 per cent grade until the apex is reached almost on line with the boundary between Switzerland and Italy. This is at 2,325-foot elevation; the bore falls thence with 7 per cent grade to the southern entrance, at an altitude of about 2,100 feet. The mountain over the tunnel is 7,000 feet in height and the thickness of rock above the tunnel at the apex is greater than in any previous work of this character.

The method adopted in carrying on the work provided for the completion of the easterly tunnel as it was driven; the floor heading of the second or western tunnel was carried along at the same time, with no attempt to complete this bore, its present use being confined to ventilation. The two bores are joined at intervals of about 650 feet by cross-galleries or traverses. While the two tunnels will ultimately be of the same size, but one will be completed at the present time; the second will be enlarged at about the middle for a distance sufficient to permit trains to pass. When traffic increases so as to demand it, the second bore will be fully completed. The double-tunnel scheme was developed in course of construction into an effective system of ventilation. High temperatures were encountered as the work progressed, and in order to make conditions more tolerable, fresh air was forced in by powerful fans at the rate of about 1,250 cubic feet per second, entering heading No. 2, passing through the last traverse and returning outward through heading No. 1. Cross-galleries or traverses were closed as the work progressed, only the advance opening being kept clear. Even with such a circulation as this, it was found necessary to further reduce the temperature at the face by sprays of cold water. For this purpose a great system of refrigeration was installed. The temperature of the rock in the tunnel was 55 deg. C., but the cooling devices maintained the air temperature at from 25 to 30 deg. C.

The construction of the tunnel was carried on simultaneously from both ends. The heading starting on the Swiss side at Brigue was pushed beyond the apex to a point on the Italian side about 6½ miles from the Swiss portal. At this time the Italian heading had been advanced to within about 800 feet of the other heading, and there remained this thickness of rock to be penetrated before the mountain was pierced. At this point, in September, 1904, unexpected obstacles to further progress were encountered, necessitating the abandonment of work on the Swiss side and seriously impeding operations in the Italian heading. These were springs of hot water at 45 deg. C., opened almost simultaneously in the two headings; those on the Swiss side flowing 489 gallons per minute, those on the Italian side 960 gallons per minute. The volume and temperature of this water in the Swiss heading, together with the destruction, by a landslide, of the cooling plant for that section, forced complete suspension of operations at that side. The work was completed by driving through the Italian heading, but here again operations were seriously impeded and the rate of progress cut down to a mere fraction of that normally maintained. When measurements showed that only a thin wall, which could be removed with one blast, intervened between the two headings, work was suspended until the greater part of the accumulated water on the Swiss side could be pumped out. Then the blast was fired, making an opening through which the remaining water rushed out to the Italian portal. This occurred on Feb. 24, 1905; and this date marks the culmination of the greatest tunneling enterprise ever attempted. The work was started in August, 1898.

Power for the Simplon work has been furnished by two plants of about 2,000 horse-power each, driven by water power, one at either end of the tunnel. The method of tunneling was radically different from that familiar to American engineers. Instead of the compressed-air rock drills so common in American practice, the Brandt system of hydraulic rock drills was used. This operates by grinding away the rock by cutters under tremendous pressure. Instead of the familiar air-compressor plant, there were immense high-pressure pumps driven from water-wheels. The ventilating fans also are driven by water-power. The tunnel section was enlarged by hand drilling.

Compressed air was used in operating the haulage locomotives handling construction trains in the tunnels. The power-house supplying compressed air to this system was installed at Brigue, Switzerland. It contains two Ingersoll-Sergeant compressors, belt-driven from water wheels; they are of the three-stage straight-line type, "class BC3," with waterjackets on the low-pressure cylinder, horizontal intercooler, and water-box submergence on the high and intermediate pressure cylinders. They deliver air at 1,500 pounds pressure and, at a normal rating of 140 revolutions per minute, each compressor has a free air capacity of 121 cubic feet per minute at this pressure.

The continuation of this great work under the unexpected difficulties encountered called for the exercise of resource and daring on the part of the engineers in charge. The driving forward of the Italian heading, in the steaming, stifling heat from the hot water, was in itself a wearing and laborious operation without precedent. Much curiosity and apprehension were felt as to the outcome of the piercing of the dividing wall. But this was made without mishap, and since that time efforts have been directed toward enlarging, lining and completion of the tunnel.

While one of the largest and most difficult tunnels, the Simplon was by no means the most expensive. Its cost thus far, exclusive of installing charges, has been about $210 per linear foot. In driving it 10,000 men have been continuously employed—4,000 on the Swiss side, 6,000 on the Italian section. Its length, as

stated, is $12\frac{1}{4}$ miles. The section of the completed tunnel is of horseshoe shape, 13 feet 6 inches wide at bottom, 16 feet 6 inches at spring line, and 18 feet high in the clear above the rails. It is lined with concrete and masonry throughout, the enormous pressure in some places calling for a lining 6 feet thick. The heading carried forward in the second and uncompleted bore is 6 feet 6 inches high and 10 feet wide.

Just what power will be used to haul trains through the tunnel has not yet been made public. A recent order by the Swiss government for 160 cars with inclosed platforms seems to indicate, however, that for the present at least, steam will be used.—The Engineering and Mining Journal.

[Concluded from SUPPLEMENT No. 1564, page 25067.]

THE EDISON IRON-NICKEL ACCUMULATOR.*

By M. U. SCHOOP.

INTERNAL RESISTANCE.

THE internal resistance of the Edison accumulator is substantially less than that of a lead accumulator of similar capacity, and is apparently independent of the discharge current strength. Thus, the average value for the first quarter of the discharges at 10 and 80 A., and an average electrolyte temperature of 25 deg. was 0.002 O. In consequence of the polarization of the concentration, it is incorrect in the case of the lead accumulator to ascertain the internal resistance by opening the circuit and observing the E. M. F. readings. From all the facts the conclusion can be drawn that in the Edison accumulator the influence of the electrolyte concentration upon the E. M. F. is so excessively slight that the values obtained by the interruption method are probably very nearly correct. In strong discharges a measurable increase in the internal resistance is noticeable near the end of the discharge. This increase depends primarily upon the decreased conductivity of the electrolyte which at the end of the discharge must be considered as divided into three layers of unequal concentration and consequently of very unequal conductivity. Further, it is partly due to the diluted pore-fluidity in the iron electrode, to the free electrolyte with invariable concentration between the plates, and to the fact that the pore-fluidity has decreased at the nickel electrode. Moreover, the temperature of the electrolyte is probably different in the separate strata. At the perforations, for instance, where the lines of current crowd together and the interchange of electrolyte layers of unequal concentration chiefly takes place, a strong heating of the electrolyte must doubtless occur.

From the above may be seen that despite the fact that the average concentration of the solution has remained unaltered during the passage of current, the conductivity of the electrolyte has undergone substantial change in consequence of formation of layers of unequal concentration.

With respect to the part played by the individual electrodes in the total resistance it appears that this is one of the few points in which the action of the Edison accumulator resembles that of the lead accumulator, in that the resistance at the negative electrode (iron, or, in the former, spongy lead) is much greater than that at the positive electrode (nickel, or, in the former, peroxide of lead). In Fig. 8 the measured values for the total resistances in charging and discharging with 80 A., as well as the component resistances are graphically shown. It is to be noted, however, that in this experiment (fourth discharge) the cell was not yet at its fullest capacity. The continuity of the curves (at least for the discharge) is an evidence that the current interruption method gives reliable results; only after the sudden fall in voltage do the readings, upon the opening of the circuit, become uncertain. At the beginning of the discharge the internal resistance is 0.0014 O., attains the value 0.002 O. in fifteen minutes, and then toward the end of the discharge, at the point when the voltage drop begins, takes a value four times as great as that of the beginning, namely, 0.0056 O. For the charging, the average value of the internal resistance is somewhat less despite a considerable development of gas. Janct (Paris) found the values 0.0025 O. at the beginning and 0.0035 O. at the end of the discharge for the D type cell which he investigated; the details of his method of investigation, however, as well as the manner of taking measurements are not at hand. The separate electrodes show a striking difference of action. The nickel electrode changes extremely little during current passage while the resistance of the iron electrode with an increasing discharge rises rapidly. The resistance curves of the individual electrodes can make no claim to great accuracy, and are only intended to show that the total resistance of the accumulator is primarily due to the iron electrode. This is also in accord with the other investigations conducted by myself, wherein I found that the active iron mass even after amalgamation with added graphite conducts badly, the nickel hydroxide mass, on the other hand, with and without graphite addition, excellently. In consequence, the frequently stated view, that the poor conductivity of the active masses of the Edison accumulator is a characteristic attribute of the same, is only partially substantiated.

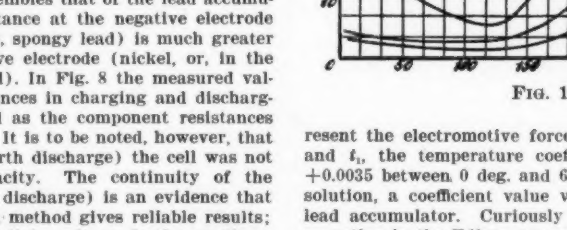


FIG. 8.

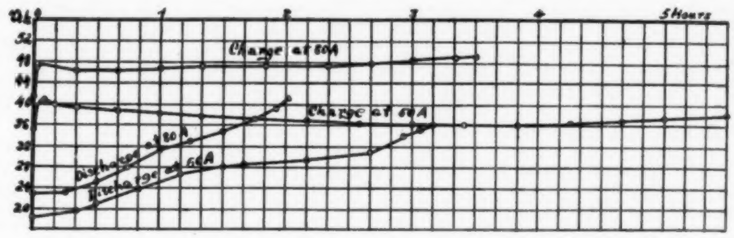


FIG. 9.

TEMPERATURE COEFFICIENT.

According to the calometric measurements of Streintz and Dolezalik, the temperature coefficient of the lead accumulator is positive in the case of the concentration usual for acid. Accordingly, the lead accumulator becomes cooler during discharge, while the charging proceeds with the development of heat. In order to determine the influence of the temperature upon the E. M. F. of the Edison accumulator, it was placed in a water-bath, and this slowly brought to a temperature of 60 deg. According to the equation

$$\frac{de}{dT} = \frac{e_2 - e_1}{t_2 - t_1}$$

where T is the absolute temperature and e_2 and e_1 represent the electromotive forces at the temperatures t_2 and t_1, the temperature coefficient was found to be $+0.0035$ between 0 deg. and 60 deg. for an 18 per cent solution, a coefficient value very close to that of the lead accumulator. Curiously enough, we can observe an action in the Edison accumulator that is apparently a contradiction to the positive temperature coefficient, in that even at slow discharge a measurable amount of heating is evolved, while in charging, the cell becomes cooler. In Fig. 9 the results of tests with 50 and 80 A. are graphically shown. In the discharge at 50 A. the solution slowly becomes warmer from 20 deg. to 28 deg., then the curve becomes flatter and not until the end of the discharge, after 145 ampere hours have been withdrawn, does it begin to rise at a more rapid rate. It is evident that the temperatures, measured perforce near the surface of the liquid, do not correspond to the instantaneous values of the solution temperatures between the electrodes, as a certain time must elapse before the heated electrolyte has risen to the top. This explains the rapid rise of the curve from 35 deg. to 41 deg., when the charging immediately follows the discharge. Also when charging with 80 A., an enormous current for an accumulator weighing only $5\frac{1}{2}$ kilogrammes, the temperature changes during the entire period are unimportant and negligible. The heat liberated in the cell during the passing of current consists of three components: the Joule heat ($= i_2 W$), the heat of dilution of the electrolyte, and secondary heat ($= n \times$ E. M. F. $\times$ 23,000 cal., where n = the valence). As the internal resistance of the cell is exceedingly small, the question arises as to what causes the decided temperature changes. It is conceivable that the temperature coefficient for the concentration arising in the pores of the plates changes its sign, or at least takes values which differ considerably from $+0.00035$. Another explanation could be based upon the theory that the heat changes of the electrolyte are primarily connected with the changes of volume of the active masses.

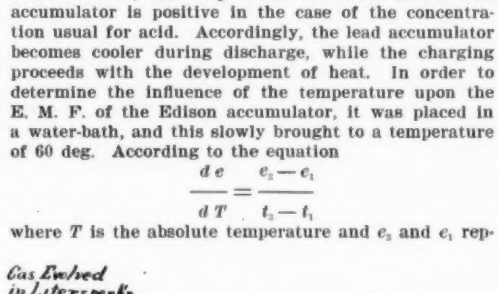


FIG. 10.

But the considerable changes in volume of the nickel mass, in comparison to the thermal fluctuations of either the FeO or the $Ni_2O_3\ 3H_2O$, can only act as a corrective. Suppose that during the current-delivering reaction, the volume changes from V to V' liters. The atmospheric pressure upon a square centimeter equals the weight of a column of mercury 760 millimeters high, that is, 7.6 cubic decimeters. As the specific weight of Hg is 13.6, the pressure per square centimeter is $13.6 \times 7.6 = 103.4$ kilogrammes. Thus work equal to $(V - V')$ 103.4 kilogramme-decimeters or $(V - V')$ 10.34 kilogramme-meters is produced by the contraction $V - V'$. As, further, 1 gramme-calorie is equal to 0.426 kilogramme-meter, the thermal equivalent for the volume change $V - V'$ is

$$\frac{(V - V')\ 10.33}{0.426} \text{ grammes-calories.}$$

The volume change during the discharge of the Edison accumulator was observed to be 0.16 cubic centimeters per ampere-hour;* for 140 ampere-hours, therefore, the total contraction $V - V'$ equals 22.4 cubic centimeters, and the corresponding thermal work is

$$\frac{22.4 \times 10.33}{0.426} = 231.4 \text{ grammes-calories.}$$

CAPACITY AND EFFICIENCY.

As we have seen, the Edison accumulator is superior to its old rival in a number of ways, but with regard to efficiency and useful effect the reverse is true, and only the future can demonstrate whether or not it is possible to improve the cell in this respect. The process of forming nickel plates electrolytically, proposed by Junger, has apparently little practical future, as the active mass of that kind of nickel Planté plates adheres poorly to the holder on account of the change in volume and so falls to the bottom of the vessel.

The lengthy investigation measurements with regard to the capacity and efficiency are not as complete, unfortunately, as their importance warrant[illegible] amount the tests were carried out for only one current st[illegible] scale and namely 40 A., in charging and discharging. [illegible] that the ures refer therefore to a discharge period of [illegible] is to be hours. The results are as follows:

Input.		Output.		Per Cent. Efficiency in Ampere-hours.	Per Cent. Efficiency in Watt-hours.
Ampere-hours.	Watt-hours.	Ampere-hours.	Watt-hours.		
258	425	143	177	55.5	40.0
212	375	141	175	66.6	46.7
186	323	138	171	74.0	53.0
164	315	135	167	79.1	53.0

From this statement it can be seen that the maximum capacity and watt-hour output can only be obtained by strong overcharging, and in consequence with a low useful efficiency, but that the capacity increases to a decided extent if the efficiency is not considered. There is nothing against the belief that with smaller current strength a better efficiency would be obtained, as in the case of the lead accumulator.

The measurements of Joly (London) with regard to the evolution of gas during chargings with various currents are of interest. In Fig. 10 are shown the respective results, which support the rather obvious opinion that the efficiency, which apparently is nearly proportional to the evolved quantity of gas, rises with decreasing current strength. The calculations from the curve show that during the charging with 100 A. × 3 hours, 140 ampere-hours were lost through the development of gas, but during the charging with 30 A. × 10 hours, only 95 ampere-hours were lost. In this connection it was assumed that the gas was similar to the theoretical oxyhydrogen gas mixture, which in fact was not precisely the case. The capacity of the cell investigated by Joly was 165 to 170 ampere-hours.

Up to the present about 50 discharges have been made with the Edison accumulator, type E, during

* Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from the Elektrotechnische Zeitschrift.

* A contribution to the theory of the Edison accumulator with constant electrolyte, M. U. Schoop. Electrochem. Ind., 1904, No. 7.

which no decrease in capacity has been demonstrated. It is impossible to draw a reliable conclusion from what has so far become known in regard to the length of life of the Edison accumulator, and the reports regarding this are often contradictory. Thus, it has been stated on the one hand that after 150 discharges a loss of 15 per cent in capacity was shown to have occurred, while on the other hand I was recently informed from the Laboratoire Central in Paris that after more than three hundred discharges a loss in capacity of only a few per cent was demonstrable in the cell investigated. These contradictions may be due to the fact that the cells leaving the Edison factory are of different quality, and this is the more probable as the production of the accumulators in large quantities has not as yet been attempted. It is true that the earlier cadmium-tin soldering had many disadvantages, and that it was the cause of the withdrawal from the market of a large number of automobile batteries. This fault has, however, been overcome in the later types by the welding process.

In studying the Edison accumulator it is most astonishing to discover that it can withstand almost every conceivable mishandling without injurious consequences, provided that the added water is very pure. The accumulator can be allowed to stand discharged as long as desired, its poles can be entirely reversed, it can be short-circuited, without any apparent effect beyond requiring a stronger overcharge to attain its full capacity, while in the lead accumulators such experiments are absolutely impossible. If the iron electrode be brought into the air in a charged condition, oxidation of the spongy iron takes place with the production of considerable heat, and the regeneration of an electrode thus acted upon is difficult. In consequence, the cell must be carefully discharged for shipment. Two which were sent to me from America were packed in hermetically sealed rubber bags, probably as a protection against the carbonic acid of the atmosphere.

It is probably little known that Edison primarily intended to produce a durable accumulator of light weight for submarine boats for which purpose, aside from high specific output and great durability, the space requirement is of greatest importance. The answer to the question, How does the Edison accumulator compare with the lead accumulator in respect to watt-hour output? is, however, of interest in other fields for its use. It is often claimed that the voltage of the Edison accumulator is far too low, and this often unconsciously induces the impression that consequently twice as much room is necessary as in the case of the lead accumulators for each unit output. Take for instance the following concrete example: Two batteries are in question, the one consisting of lead, the other of Edison cells, both batteries of equal voltage and equal output. For simplicity assume the voltage of a lead cell as 2 V, that of an Edison cell as 1 V so that n of the latter cells and $n \times 2$ of the former are necessary. The herein investigated Edison accumulator, type D_{18}, has an output at a three hours' discharge of 178 watt-hours, with a jar volume of 2,559 cubic centimeters or 14.3 centimeters per watt-hour. The lead battery must yield $178 \times 2 = 356$ watt-hours in a three-hour discharge. A glance at the various catalogues will show that the volume of such an element is at least 5,600 cubic centimeters and therefore 16 cubic centimeters per watt-hour is the corresponding figure for the lead cell. Even with the assumption, unfavorable to the Edison accumulator, that the lead cell has a voltage twice as great, [illegible] Edison cell is still superior. It is to be remarked [illegible] this connection the latest Type E possesses a [illegible] advantage over the older forms. [illegible] calculation is made in a similar manner for two batteries, which in this instance contain the same number of cells, so that the lead accumulator possesses a voltage twice as great as that of the Edison accumulator, the result is still more decidedly unfavorable to the former than in the first parallel. In answering the space question, one must not lose sight of the fact that there is no objection to placing the lead cells close together, a procedure which is not feasible for the Edison accumulator. Apparently this again reduces the advantages of the latter when in complete batteries.

SUMMARY OF RESULTS AND FINAL OBSERVATIONS.

1. The capacity of the Edison accumulator under normal temperature conditions is independent of the current strength, and the watt-hour output is comparatively small. The latter varies between 31 and 35 watt-hours per 1 kilogramme of total weight of cell. One volt is the lower limit value.

2. The accumulator withstands rough and careless handling without injury. As, with the exception of the active masses, the materials of construction throughout consist of nickel sheet steel and hard rubber, the accumulator is also capable of withstanding decided mechanical shocks and vibrations.

3. Ampere and watt efficiencies are lower than in the lead accumulator, and at an average do not exceed 75 per cent and 55 per cent. It may be added that with the very short charges and discharges which the Edison accumulator stands without the least injury, the efficiency varies very little from the given value. A lead accumulator would under the same conditions give an efficiency value which would surely be little different from that of the Edison accumulator. It is to be further remarked that reliable data regarding the efficiency in electromobile batteries in practical use are seldom obtainable. In consequence of the almost universally present connection with the frame of the carriage and the usual moist condition of the hard-rubber cases, it may be assumed with certainty that the efficiency in such batteries deviates considerably from the values obtained upon the laboratory table.

4. On a basis of equal performance the volume of the Edison accumulator is less than that of the lead accumulator. The difference, however, is probably equalized to a certain degree in that the cells of the lead accumulator can be placed close together, a proceeding not possible with the Edison accumulator.

5. The attention necessary for the Edison accumulator consists only in refilling the same with pure water.

Whether or not the Edison accumulator will fulfill its expectations in continued use is a question the future alone can decide, as at present a conclusion can be drawn from an operation of only a few years' duration.

Opinions differ regarding the credit due to Edison in respect to priority of invention. Whatever opinion one may hold, however, the fact remains beyond doubt that Edison with his characteristic persistence has followed the path toward his chosen goal, and that if the accumulator industry at this time receives a strong and healthful impulse, it is primarily due to his efforts.

I wish to emphasize that through the Edison accumulator no new principles or no new formulation of the problem of storing electrical energy has been advanced. The only general difference between the processes in the iron-nickel accumulator and the lead peroxide-lead accumulator is that in the former the electrolyte takes no active part in the current production, while in the lead accumulator the electrolyte changes from the liquid to the solid state with the formation primarily of sulphate.

In my estimation it will be a mistake to proclaim the Edison accumulator a new epoch-making idea, the fruitfulness of which can not yet be estimated, and which will furnish material for inventive ability for years to come. The importance of Edison's invention lies elsewhere, namely, in showing that admirable individual successes may be attained when working with persistence and energy on lines which are apparently without the slightest prospect of future achievement.

USE OF THE EARTH IN HIGH-TENSION TRANSMISSIONS.

By EMILE GUARINI.

ELECTRICIANS, especially those of the International Society of Electricians at Paris, have for some time past been occupying themselves with the question of the services that the earth may render in the transmission of electric energy to a great distance, and the French government has even appointed a commission to make a profound study of the problem. This commission, presided over by M. Harké, has made a series of experiments at Lancey (Isere in France) with the aid of M. René Thury, engineer-in-chief of the Compagnie de l'Industrie Electrique et Mecanique of Geneva, who had already studied this interesting question and obtained some remarkable results that mark an epoch in the history of the transmission of electric energy to a great distance. This society, in fact, succeeded in transmitting a current of 150 amperes at 23,000 volts from Saint Maurice to Lausanne (Switzerland) a distance of 56 kilometers (34¾ miles), making use of the earth as a return conductor. In the Lancey experiments made by the French commission, the results were, from several points of view, remarkable. The current employed was a continuous one of 210 amperes. The experiments confirmed the preceding results; that is to say, the loss was proportional to the intensity. The most important fact established was that the *zone electrified extended to short distances from the earth.* At less than 100 meters there was no longer any very perceptible difference between two points of the ground. The almost total fall in voltage occurred in the immediate vicinity of the ground plates, especially in the first meter.

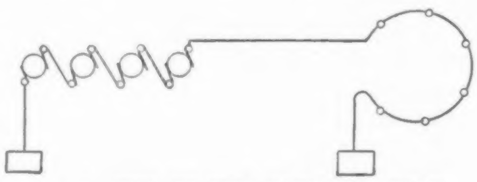


FIG. 1.—USE OF THE EARTH IN HIGH-TENSION TRANSMISSIONS.

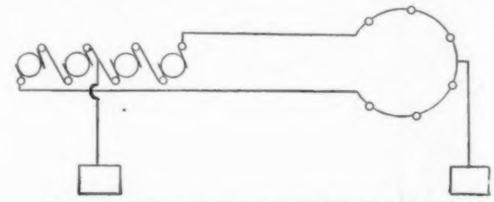


FIG. 2.—USE OF THE EARTH IN HIGH-TENSION TRANSMISSIONS.

These results are absolutely in accordance with those of the experiments recently made by us and that proved to us that in tramways the rails do not serve to return the current to the works, and that at about 250 meters from a car absorbing 100 amperes there is no longer any current in the rails.

Another interesting fact learned was that no telephone or telegraph disturbance exhibited itself. This might appear to be in contradiction to a well-known phenomenon. We know that certain experimenters have been able to telegraph to a distance of several kilometers by utilizing the conductivity of the ground. This is explainable by the fact that a current of constant intensity was employed. Now, it is the intensity alone that enters into play in this kind of telegraphy.

Let us suppose, in fact, a telegraph circuit of determinate resistance comprising a Morse registering apparatus. The current that traverses the instrument will be so much the more intense in proportion as the difference of potential between the two ground plates of the telegraph circuit is greater. Now, such difference of potential ($E = I R$) is so much the greater in proportion as the resistance of the earth between the ground plates is higher and the intensity of the current that traverses the earth is greater. Since the resistance of the earth is a matter of no account, even when the plates are quite distant, nothing remains in play but the intensity, as we have above stated.

About a year ago we proposed to replace the neutral wire of a three-wire transmission by two plates. We remarked that if the intensity of the current traversing the two circuits was equal, not only should we have the advantages that we obtain when we replace a conductor by the ground, but would also abolish all disturbances upon telephone and telegraph circuits utilizing the earth as a return conductor.

And now M. Thury proposes to use the earth as a resistance to static tension. Before explaining this interesting matter, let us examine the rôle that the earth may play in installations of transmission of power to a great distance, and let us take as a basis the results obtained by M. Thury and the French commission of electricians.

By the use of the earth the amount of copper in weight required is reduced by one-quarter. There is also a saving of three-quarters of the energy lost through ohmic resistance, with an equal expense for copper. It is usually preferred to divide the two advantages by saving half of the expense of copper, while at the same time doubling the efficiency of the line. This results from the fact recently found by experiment that the ohmic resistance of the earth is absolutely of no account for the usual industrial currents, which are always very weak, since they do not at a maximum exceed a few hundreds of amperes. The resistance alone of the contacts to the earth plays an appreciable rôle, and may be easily rendered so weak as to be sensibly of no account; and such rôle, in one case, may itself have no influence whatever upon the efficiency, just as if the resistance of the ground plates and of the earth itself were exactly equal to zero.

The following are the two different ways in which the Compagnie de l'Industrie Electrique et Mecanique, of Geneva, makes use of the earth:

(1) By utilizing it purely and simply in place of one of the two conductors necessary for the passage of the continuous current (Fig. 1). In this case, the maximum tension for which the line should be insulated is equal to the maximum tension capable of being given the generators. It will be possible to utilize this system, then, only at the tension which the entire material of the line and machines will be capable of resisting, taking into account the necessary coefficient of safety. The loss of the earth will be that solely of the two points of contact, of which the resistance may be very easily reduced to one ohm at the most, according to M. Thury, and to 1-100 of an ohm according to our own experiments. This is of some importance as regards currents of low voltage and great intensity.

(2) By utilizing the earth as a resistance to static tension (Fig. 2). In this case, the earth no longer plays the part of a conductor, properly so called, except in case of damage as a spare line. This method, according to M. Thury, is the only one that can be utilized in the transmission of power to a great distance.

What interest can there be in utilizing the earth only as a resistance of tension? Why not employ it simply according to the first method, that is to say, as a return conductor? Because, from an economic point of view, there seems to be no difference between the two methods, and the second has a few advantages that the first has not, and, among others, that stray currents are normally abolished, and, in exceptional cases, reduced by one half. Another advantage, and a very notable one, is that the earth forms a spare line that is always disposable, while in the first method, if a spare line be desired, it is necessary to install it in the form of a complete arc.

How is it that the earth, not used as a transmission line, can nevertheless afford in the second case the same advantages as in the first, that is to say, the reduction, by 75 per cent, of the weight of the copper necessary for the transmission of the current or the energy consumed in line losses? It is because the means that the industry has now at its disposal do not permit of practically exceeding a certain static tension, that is to say, a certain difference of tension between the lines, machines, and various apparatus on the one hand, and the earth on the other. The second method brings to the terminals of the generators double the amount of such tension without increasing the tension between the lines and the earth. It is in this way that the difference of tension capable of existing between any point whatever of the line and the earth through the grounding of the neutral wire is reduced, by one-half, in a large number of three-wire electric installations.

What is the maximum tension admissible between the earth and the circuits? The experiments made by the Société de l'Industrie Electrique et Mecanique, of Geneva, have demonstrated that a continuous static tension of 20,000 volts between the earth and the lines gives rise to no appreciable loss.

In damp weather, with a fog prevailing over the valley of the Rhone and Lake Leman, the losses rose to a total of 0.01299 ampere, a mean of ten readings at a tension of 20,000 volts. The loss was found to be equal to 0.0866 of a watt per insulator. There were nevertheless 15 line insulators whose tops had been maliciously damaged. The loss was therefore but 260 watts, say, 0.00009 of the energy of the current transmitted, a quantity of absolutely no account.

The experiments performed on the other hand with alternating current gave, as the amount of the losses, figures much larger than those that we find with continuous current, and yet it is at present admitted that a tension of 40,000 compound volts is acceptable. M. Thury admits, as nearly equivalent, a continuous tension of from 56,000 to 60,000 volts, and this view is confirmed by the experiments that he has recently made at such voltages.

Let us therefore grant provisionally that the critical point is a tension of 50,000 volts. The use of the earth as a return conductor will limit the tension at the exit from the generating works to this maximum one. In order to transmit 10,000 kilowatts it will be necessary to adopt an intensity of 200 amperes and for a distance of 150 kilometers to employ a cable of 200 square millimeters weighing 540 tons for a loss of 10 per cent, or a cable of 100 square millimeters weighing 135 tons for the same loss with a return by the earth. If the earth be employed as a neutral wire, that is to say, as a tension resistance, 100 amperes solely and twice 50,000 volts requiring two 50 square millimeter conductors weighing 135 tons will suffice, the loss admitted remaining 10 per cent as above. Nothing will be changed either in the losses by insulators or in the static effects of the current, and there will be nowhere any chances of accident, the maximum tension remaining limited to 50,000 volts against the earth.

The only difference resides in the line, which will be of smaller section and will have twice as many insulators. The grounding is done simply at the generating works at a point of the circuit having half the total number of generators in series on each side. Other groundings are effected toward the center of the working circuit, but are connected with the latter only in case of accident or repair upon one or the other of the two lines. In case of the interruption of a line, only half of the total energy is employed.

CONTEMPORARY ELECTRICAL SCIENCE.*

ELECTROLYTIC DETECTOR.—G. Ferrié describes some further developments of his electrolytic detector, which, invented in 1900, has since been utilized for wireless telegraphy by Schlömich, de Forest, and others. A platinum wire 0.01 millimeter in diameter just dips into sulphuric or nitric acid, and the cell is placed in a telephone circuit. A train of incident waves may be "read" in the telephone over some 12 miles. But the sensitiveness of the apparatus may be considerably increased by introducing an E.M.F. into the circuit with its positive pole joined to the platinum. The sensitiveness increases with the E.M.F. as long as the latter remains below the point at which electrolysis set in. This point can be ascertained by means of a potentiometer. When it is passed, a continuous hissing is heard in the telephone. If the latter is replaced by a ballistic galvanometer, every wave-train is indicated by a deflection, which is reversed on introducing the E.M.F. This curious fact may be explained on the assumption of a depolarizing current. When at rest, the E.M.F. produces a counter E.M.F. of polarization in the detector cell, which forms a kind of condenser subject to discharge by impinging waves, the necessary conductivity being created by a kind of coherer action. —G. Ferrié, Comptes Rendus, July 31, 1905.

DISCHARGE POTENTIALS.—According to E. Bouty, the critical field beyond which a gas gives way to an electric charge is the sum of two terms. One of these is characteristic of the gas, and independent of the temperature when the mass and volume are kept constant. It greatly preponderates at pressures above a few tenths of a millimeter of mercury. The other term, which only comes into force at very low pressures, depends essentially upon the dielectric substance of the wall and upon any gaseous layer which may be adhering to it. When the second term is negligible, the possible difference of potential between two electrodes may be written $= a\sqrt{pe(pe + k)}$, where a is the dielectric cohesion of the gas, p its pressure, e its thickness and k a constant varying with the gas. For the same gas, this difference of potential only depends upon the product of pressure into thickness, or, in other words, upon the quantity of gas affected by the discharge. In the case of large masses, the discharge potential depends upon a constant quantity amounting to about 1,760 volts for air, and upon another term amounting to 2.46 $\times 10^7$ volts per gramme of air traversed per square centimeter. At high altitudes the possible field would become so small that the air cannot even support the earth's electric field without giving way.—E. Bouty, Comptes Rendus, July 31, 1905.

MAGNETIC DOUBLE REFRACTION.—A. Cotton and H. Mouton shed some further light on the curious phenomenon first described by Majorana in 1902, in which solutions of colloidal iron in a magnetic field behave like positive or negative uniaxial crystals having their axis parallel to the lines of force. When a ray is transmitted normally to the lines of force its components parallel and perpendicular to the field show a difference of velocity. This phenomenon is best exhibited by the preparation known as "Bravais iron," especially when matured by age. The authors attribute it to the presence of ultra-microscopic particles. If the liquid is filtered through collodion the residue shows the phenomenon greatly enhanced, whereas the filtrate ceases to show it. The liquid becomes inactive when coagulated, but when the coagulation is brought about in the presence of the magnetic field it remains, and does not disappear entirely on withdrawing the magnetic field. The authors found, further, that both components of the ray are affected by the field, but that the vibrations parallel to the lines of force undergo a diminution of refractive index which is nearly double the increase experienced by the other components.—A. Cotton and H. Mouton, Comptes Rendus, July 31, 1905.

METALLIC RADIATION AT ORDINARY TEMPERATURES.—G. Melander, of Helsingfors, has sought an explanation of the fact that snow is visible even on the darkest cloudy nights, a fact which he attributes to a slight degree of proper luminosity possessed by the snow. He exposed photographic plates in metallic boxes to the light of the snow, and found them uniformly blackened after a night's exposure. This blackening was not intercepted by cardboard. The author next tested for any radiation possessed by metals. With a six months' exposure he obtained some results from zinc, but the result became much more pronounced on slightly heating the metal. The heating was accomplished by means of an electric current. A convenient method consisted in sending a current through a rod of bismuth and of antimony in succession. A current of 5 amperes was sent through from antimony to bismuth for 25 hours. On development, a strong blackening was found under the bismuth, and a weaker blackening under the antimony. On reversing the current, the result was the same qualitatively, only feebler. A zinc and copper couple shows no such effect. The influence of the plates cannot be blown away with an air current, and is therefore due to some form of radiation. The pressure of the air has no influence. Hydrogen peroxide is not the agent in this case.—G. Melander, Annalen der Physik, No. 9, 1905.

MEASUREMENT OF ACCELERATION.—F. W. Lanchester describes an instrument for the measurement and recording of starting and stopping efforts in vehicles. He calls it an "accelerometer." The fundamental principle on which the instrument works, is that the effect of the algebraic sum of tractive forces and resistances on the vehicle as a whole is shared proportionately by every portion of its mass, and that consequently the tractive effort on the whole vehicle can be ascertained if that acting on any portion of its mass be measured. This tractive effort is measured by the deflection of the heavy bob of a very short pendulum, the tangent of the angle of deflection being proportional to the acceleration, and being measured by a pointer prolonging the pendulum upward and passing over a horizontal scale. The vibrations of the pendulum are damped by a dashpot. When the gradient varies the instrument no longer measures the acceleration, but it continues to measure the actual tractive effort in every case. Some diagrams taken with the instrument show the sudden stoppage of the retardation when a train is brought to a standstill, giving the impression of a jerk backward, so noticeable on the English railways.—F. W. Lanchester, Philosophical Magazine, August, 1905.

GLOW DISCHARGES IN HALOIDS OF MERCURY.—The work done up to the present in potential gradients and cathode falls has been chiefly concerned with nitrogen, helium, argon and mercury vapor, these gases being least liable to change under the electric discharge. W. Matthies has extended it to the chloride, bromide and iodide of mercury, heating the salts by means of a Bunsen burner till the necessary vapor pressure was obtained, but keeping the temperature within the range in which the lines of pure mercury and the lines due to the compounds appear simultaneously. While that is so, it is certain that the compounds are not decomposed by the discharge, though they are easily decomposed, even without a current, when aluminium, copper, iron, or mercury is present in the tube. The author found very high potential gradients and cathode and anode falls as compared with nitrogen. Thus the cathode fall in $HgCl_2$ is 365 volts. Moreover, it increases with the atomic weight of the haloid, becoming 395 in $HgBr_2$ and 432 volts in HgI_2. The gradients increase with the pressure, more rapidly than the latter at first, and then more slowly. In $HgCl_2$ vapor the gradient decreases as the width of the tube increases. The dependence of the gradient on the current intensity is very complicated, especially at high pressures.—W. Matthies, Annalen der Physik, No. 9, 1905.

COHERENCE AND IONIZATION.—The two main theories of coherer action are based upon mechanical welding and upon ionization respectively. R. Thöldte points out that either theory by itself is unable to account for the whole of the phenomena. He proves in a direct manner that the functioning of a coherer is strongly influenced by the ionization of the air in which it is immersed. He tied a radium preparation under a coherer, and left the combination at rest for 24 hours. He then found that for any current strength in any direction the galvanometer exhibited a deflection. Another series of experiments showed that oscillations which were unable to bring the coherer into action made it cohere if it was at the same time exposed to radium rays. Electric oscillations produced by a coil of known resistance, inductance, and capacity may be used as a measure of the amount of ionization in a coherer. The resistance of a coherer is reduced to a measurable amount by the presence of the radium, even when the critical difference of potential is not attained. When it is attained, the resistance is reduced beyond the normal coherence. The conductivity of a coherer is a function of the electric oscillations and of its internal ionization. The author does not know whether the latter is permanent when produced by radium.—R. Thöldte, Annalen der Physik, No. 9, 1905.

HELIUM FROM ACTINIUM.—Ramsay and Soddy have proved that radium, in the course of its disintegration, gives rise to helium, the latter being expelled as a gas, and probably made up of the α-particles expelled from the radio-active substance. A. Debierne now shows that actinium also produces helium in the course of its disintegration. The gas is found in the mixture of hydrogen, oxygen, and other gases resulting from the decomposition of the water in the salt. The oxygen is absorbed by heated copper, the hydrogen by hot oxide of copper and phosphoric anhydride, and the nitrogen by pure lithium. The gases of the argon family remain unabsorbed. They are led into a capillary tube provided with platinum electrodes, and their spark spectra are examined with a direct-vision spectroscope or photographed. The same helium spectrum is obtained with radium salts and actinium salts. When special provision is made for the elimination of radium, the results from actinium salts remain the same. When there are neither radium nor actinium salts present, a detonating mixture of hydrogen and oxygen gives no trace of helium. Though the evolution of helium is nearly the same in radium and actinium preparations, the evolution of emanation is much slower in the case of actinium salts.—A. Debierne, Comptes Rendus, August 14, 1905.

* Compiled by E. E. Fournier d'Albe in the Electrician.

SILICIDE OF MANGANESE—A NEW COMPOUND.

M. EM. VIGOUROUX, of Paris, has lately brought out a new process of reducing metals in connection with silica, and also obtains a new compound, the silicide of manganese. Following the researches of M. Henri Moissan upon the reduction of boric anhydride by magnesium, the author undertook a series of researches relating to the decomposition of silica either by magnesium or by aluminium. The action of powdered silica and magnesium has already been observed by Phipson, Parkinson, and others, who found that they produced very strong explosions, and since then by Winckler, who observed that by heating as small an amount of the powdered mixture as 0.2 gramme, flames came out of the tubes and caused them to break. Some time ago the author showed that these explosions were due to the humidity contained in the powders. By drying them he was able to use several hundred grammes in the reactions without any trouble. Besides, we do not need to heat up the whole mass in a furnace. Simply placing the flame of a match against it so as to ignite a few particles of magnesium is enough to start the reaction, which is then propagated through the whole mass. The silicon which is thus set free is melted by the heat of the reaction. This is analogous to the method which is now used for preparing metals by reducing their oxides by aluminium powder. However, in the case where we use chemically pure bodies it is sometimes difficult to obtain the complete fusion in the laboratory tests, as the small portions which are used lose more heat proportionally than a large mass, and besides we have not the small amount of impurities which come in on a commercial scale and lower the fusion point. The author finds that the oxide of the metal which we are to obtain is to be chosen in a higher order according as we require more heat for the melting. Thus to prepare a few hundred grammes of chemically pure melted chromium we incorporate into the mixture of sesquioxide Cr_2O_3 and aluminium, a certain quantity of powdered fused anhydride CrO_3. On the contrary, in preparing melted iron, in order to prevent the projection of matter which sometimes occurs with fine powders, we often add to the sesquioxide Fe_2O_3 a certain quantity of magnetic oxide Fe_3O_4. For some time past we also reduce mixtures of metallic oxides, and in this way we obtain $SiMn_2$. This body has already been prepared by the author, and then by M. Lebeau, who used his silicide of copper method. We mix powder of silica, brown oxide of manganese and aluminium, all in the purest possible state. The crucible is lined with a pure and very hard and thick magnesia layer, compressed into place by hydraulic pressure. The starting charge is formed by mixed aluminium and oxide of manganese powders. After the reaction, the material is allowed to cool slowly. In one experiment he takes 120 grammes of silica, 300 grammes of manganese oxide and 150 grammes aluminium. The reaction is easily produced with great heat. After cooling we find in the crucible a melted mass weighing 120 grammes. By washing with water and hydrochloric acid we obtain small crystals which correspond to the formula $SiMn_2$. This body may be called *mangano-silicon*. It is attacked by hydrochloric and nitric acids, with formation of silica.

COPYING PENCILS.

RED PENCILS.—2 kilogrammes of ponceau creosote are dissolved in 6 kilogrammes of a shellac soap solution, and to the mixture are added 40 grammes of gum tragacanth powder and 40 grammes of albumen dissolved in 120 grammes of water; 4 kilogrammes of prepared cinnabar (vermilion) are stirred into the mass, and the whole evaporated in a water-bath, with constant

stirring, at a temperature of 50 deg. R. (145 deg. F., 62.5 deg. C.) until it has reached a consistency where it can be pressed into sticks. Moist albumen, as well as gum tragacanth, is used for a binding medium, as the former has a special effect in making the coal-tar dyes dissolve more rapidly, and also greatly increases the hardness and durability of the pencils. The shellac soap solution gives the ponceau color a more vivid shade, as well as greater permanence and solidity. It is prepared by dissolving 60 grammes of rosin soap in 6 kilogrammes of water, and 40 grammes of shellac are then dissolved into this by boiling. The rosin soap is made by saponifying 2 parts of colophony and 80 of palm oil with caustic soda. The prepared cinnabar is a mixture of equal parts of the best cinnabar with kaolin; it is very finely ground in wet mills, dried, and pulverized. In order that the pencils made from the above mixture may not absorb moisture in damp weather, thereby becoming bent and flexible, they are covered with a good oil varnish.

Blue Pencils.—2 kilogrammes of the best water-soluble aniline blue are dissolved in 4 kilogrammes of water, and boiled. Into the solution, after cooling, are stirred 20 grammes of gum tragacanth powder and 4 kilogrammes of prepared Milori blue in its finest powdered form. As the water-soluble aniline blue is prepared with sulphuric acid, and this must be neutralized with soda, it contains a considerable quantity of sodium sulphate, which prevents intimate combination, and causes eruptions of Glauber's salt. To remove this, the pencils, after pressing, are exposed for several days to damp air, and the sodium sulphate crystallizes out. The eruptions are brushed away with damp cloths, and this is done several times, until there is no more efforescence. The mass is then moistened with water, in which 80 grammes of sugar have been dissolved; 20 grammes of the finest albumen, dissolved in 120 grammes of water, and poured through a fine gauze sieve, are added, and also 500 grammes of indigo carmine. The whole mass is now brought to the required consistency in the water-bath, at a temperature of 55 deg. R. (69 deg. C., 156 deg. F.).

The prepared Milori blue consists of 1 part of Milori blue to 6 of finely washed kaolin, ground in wet mills, dried, and pulverized. To heighten the color, one-half of one part of English sulphuric acid is added before grinding. To protect the pencils from moisture, they are coated, similarly to the red ones, with oil varnish. The sugar takes up the last little particles of sodium sulphate, and is essential to the making of firm and durable pencils.

Black Pencils.—110 grammes of ponceau creosote, 150 grammes of water-soluble aniline blue, and 10 grammes of gum tragacanth, together with 10 grammes of the finest albumen dissolved in 30 grammes of water and filtered, are dissolved in 1 kilogramme of hot water, and 340 grammes of finely ground, unctuous clay, 80 grammes of indigo carmine, and 30 grammes of India ink are added to the concentrated solution. From the mixture results a stiff mass, which, after repeated pressings and the removal of the crystallized sodium sulphate, is at last ready to be formed into pencils.—Neueste Erfindungen und Erfahrungen.

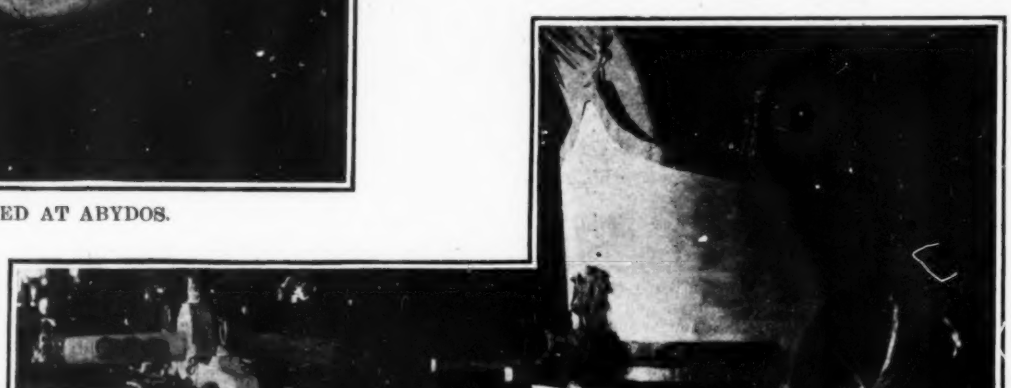
ARCHÆOLOGICAL EXHIBITION AT PARIS.

By the Paris Correspondent of Scientific American.

The exhibition which was held not long ago at Paris by the new archæological society (Société Française de Fouilles Archéologiques has been of more than ordinary interest. The collections which were assembled at the Smaller Palace of the Champs-Elysées represented the recent work of excavation in different countries. We already had occasion to illustrate the remarkable finds which were made by M. Gayet at Antinoë, and at present wish to show some of the other archæological work which has been done by the members of this new and active society.

Among the most striking and no doubt the most ancient of all the collections which are shown here are the numerous objects which have been brought to light by M. Amelineau, a well-known archæologist of Paris, during the remarkable excavations which he carried on at Abydos. These excavations were made for the most part during the period from 1859 to 1898. The objects in the present collection, which will be observed in the different views we show here, include pottery, vases formed of soft or hard stone, flints and various utensils which were employed in ordinary usage, primitive tools, and similar objects. The specimens which were found at Abydos do not all belong to the same epoch, but on the contrary they cover a period ranging from prehistoric times down to a few hundred years B. C., from the ancient empire to the time of the Ptolemies. Most interesting of all are the specimens which date from the period of Egypt which lies far back of any historic records. A number of the vases and differently formed vessels are cut out of very hard varieties of stone, and these specimens are of the highest antiquity. The most recent of these vases dates from a period at least 5,000 years B. C., and some archæologists assign them a thousand years back of this. They are anterior to the first dynasty, and the most ancient specimens were found in the tombs of the Pharaohs which are usually assigned to a period anterior to Menes. The vessels which are formed of stone show in a very striking manner the great skill in working different materials which the Egyptians possessed even at this remote age. Some of the vessels have the form of concave plates or bowls, the largest being about 14 inches in diameter. Many of them are cut out of onyx and similar hard stones. The execution of the vases is still more remarkable. One of these which will be noticed in the foreground is of a perfectly elliptical and rather flat shape and is cut out of a stone which resembles granite. The inside is hollowed out just as in an ordinary pottery vase, and this must have taken considerable work. What tools were used to cut the hard stone is not known. In the present collection it was designed to show a representative lot of the different forms and materials used in the Prehistoric and also in the later periods. The stone vessels are of an elegant appearance, but must have been difficult to carry about.

VASES EXCAVATED AT ABYDOS.



A THRACIAN CHARIOT.

Besides the stone vessels there are several specimens of a reddish colored pottery, and one piece will be noticed which is decorated with a design formed of simple lines which are rudely traced with a red coloring matter. The collection also contains one of the most ancient images. The lower part from the waist downward is covered with hieroglyphics; the lower end which formed the base of the image has been broken off. It must be remarked that the objects which are represented in M. Amelineau's collection were not all found intact. In many cases they were broken into a greater or less number of pieces, and it took considerable skill to put them together again. As a whole, the collection is a valuable addition to the Egyptian series and shows what remarkable skill and ingenuity the artisans of that early time possessed in order to produce such elegant forms in spite of the extreme hardness of the material.

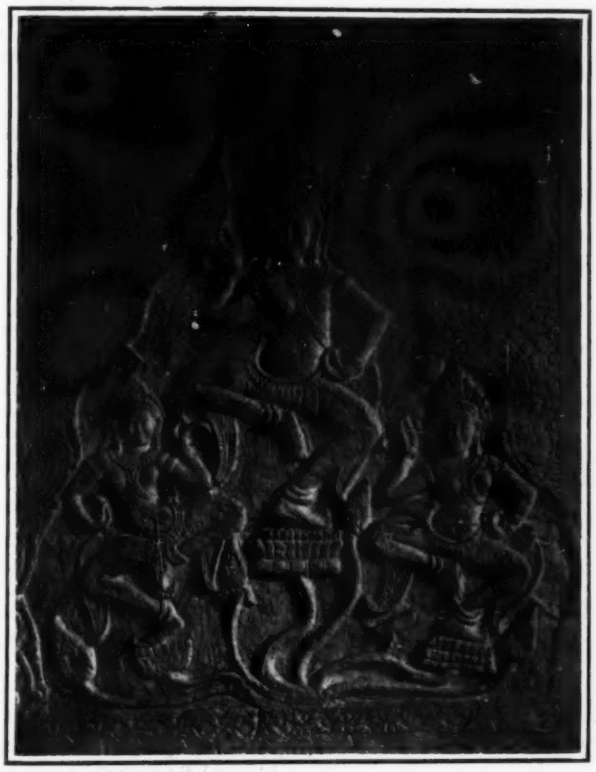
The specimens which have been sent by the French School of the Extreme Orient serve to show what kind of work this very valuable institution has been carrying on during recent years. Most of the specimens have been found by the members of the Dufour-Carpeaux expedition, which was headed by Charles Carpeaux, a promising young archæologist, of Paris, recently deceased. Some of the first excavations were made in Indo-China at My-Son, and among the most remarkable finds at this point is a set of gold jewels which were intended to be used as part of the adornment of an image. A few years before this, the school had undertaken a series of excavations at Bayon (Angkor-Thom), and some important pieces of architecture were brought to light. More recently the work was recommenced at the same point, and it continued to show a number of specimens of great interest. Some of the most recent pieces which were found mainly by M. Carpeaux in connection with M. Dufour, representing the French Académie des Inscriptions et Belles-Lettres, are shown in the present collection. The specimens of the greatest interest are a series of plaster casts which have been made from the panels in bas-relief forming part of the discoveries at Bayon. They represent various scenes of the characteristic design which belongs to that region of Indo-China. One of the relief panels shows a *motif* which is made up of lotus flowers and three divinities in a dancing posture. A second panel is covered by the representation of a religious ceremony or cortege, in which a six-wheeled chariot bearing the images of the divinities is drawn along in state, accompanied by a large procession which carries a series of ensigns of a very curious character. At the lower part of the relief is another part of the procession, where the persons carrying various instruments or weapons are seen to pass in a long file.

M. Moreau de Neris has been engaged for some time in making excavations on the site of the ancient Roman town of Neris, which was one of the flourishing towns of ancient Gaul. It was especially noted for its baths and seems to have been a much-frequented resort during the Roman period. M. de Neris has been able to locate most of the principal buildings, among which the most important is the great bath establishment, including a main building which is provided with hot and cold rooms, like the baths at Pompeii and elsewhere. In front of it is the temple of Diana, and behind it an immense pool or artificial lake where naval battles were given. The specimens which are shown in the present collection relate mainly to the different objects or utensils which were found at Neris. It is hoped to give a special description of this interesting site in the near future.

Two of our engravings show a part of the interesting collection belonging to Prof. S. Pozzi, vice-president of the society. The specimens which M. Pozzi loaned to the exhibition come from Greece, Italy and other Mediterranean countries. Some fine Etruscan specimens are to be seen. In the foreground of one of the views is a vase of pottery in the form of a ram. The orifice of the vase is placed just back of the head. A number of small figures are seen near it, and to the left is a plate of the archaic style. A remarkable piece is the

torso, probably of Venus, which one of the engravings shows.

Prominent among the specimens is the Thracian chariot, which has been restored by a young archæologist of note, M. J. P. Gérard. The bronze pieces of the chariot, which were all that remained, were sent to Paris by **M. Simoes da Fonseca.** The remainder was no doubt of wood, and owing to the form of the bronze pieces, the original form of the chariot could be reconstructed after some study. The chariot is decorated with *motifs* and groups taken from the legend of Bacchus, and these are of a highly ornamental character.



PART OF A SCULPTURED BAS RELIEF.

THE ROMAN CATACOMBS.*

Among the mingled feelings to which a first acquaintance with the catacombs is likely to give rise, will be one of bewilderment at the seemingly endless extent of their ramifications. It has been roughly calculated that if all the underground galleries and passages could be placed end to end in one long line, they would more than traverse the entire length of the Italian Peninsula, and that the graves inclosed in their walls would amount to at least two millions. Startling enough in itself, such an estimate as this throws an interesting light on the rapid spread of the Christian religion in the capital, since it can have been no stagnant or insignificant society which, even long before the "Peace of the Church," had come to require such an extensive area for its dead. But so meager and fragmentary are the records of this primitive Christianity that our knowledge of the details concerning its growth and progress is necessarily very imperfect, while with regard to its ancient burial-grounds, we must accept the fact that for some three hundred years their history can only be even partially recovered by aid of the concurrent testimony of archæology and tradition. . . .

We are no longer invited to believe that the Roman catacombs were in their origin neither more nor less than disused sandpits. Nor would the view that their excavation was carried on secretly and by stealth find any support at the present day. Such a work must obviously have involved the displacement and removal of many thousand tons of soil, and to suppose this to have been carried out so as to evade the vigilance of the police of the capital is, as Mommsen long since pointed out, to impose too severe a tax upon our credulity. And, lastly, it is admitted that, although on the occasion of a funeral and of its anniversaries, it was the primitive custom to celebrate the Eucharist at the grave, the catacombs were, in point of fact, originally planned and designed to serve neither as subterranean places of worship, nor yet as asylums of refuge from persecution, but simply as cemeteries for the use of the Christian community.

It may assist us to understand how the Roman catacombs had their origin if we picture to ourselves the position in which, as years passed by, the Christian population would find itself placed in dealing with the problem of making suitable provision for the dead.

But for one restriction the laws of Rome presented no difficulty. Interments by Christians must follow what was the general rule and be made outside the city walls. Subject to this condition, the new sect might lawfully adopt whatever mode of burial they pleased, in the full confidence that their cemeteries would receive exactly the same protection which the municipal authorities were most watchful in extending to all tombs and sepulchers. Looking round upon the customs of contemporary paganism, the early converts would find more to repel than to attract them. Cremation, at the period with which we are dealing, had all but entirely taken the place of inhumation. For wealthy families of position there were the stately mausoleums which flanked the great Appian Way. For humbler people there were the dove-cots of the various "columbaria," into which, at but little expense, their ashes might be received when the fire had consumed their bodies. For the dregs of the populace there were filthy pits like those that as Horace tells us (Sat. I., viii. 8) used to defile the Esquiline, into which their corpses were flung like so much carrion and left to rot.

But the mausoleum, with its sarcophagi of sculptured stone—so costly in construction and so burdensome to carry to their destination—and with its note, moreover, of aristocratic exclusiveness, was but ill adapted to meet the growing needs of a spiritual democracy, the great majority of whose members were of very slender means, and whose religious principles admitted of no distinction between rich and poor, master and slave. Cremation, too, was distasteful to Jew and to Christian alike, and under the influence of the new teaching as to the resurrection of the body, it passed more and more into disuse. "Christians," writes Minucius Felix, "hold cremation in abhorrence." "We," he adds, "follow the venerable and better custom of interment." Accordingly, there remained only the "commune sepulchrum," the common grave of the outlying pits. For men, however, who had but just learned that nothing which God had cleansed should be held common or unclean, it would instinctively be felt a sacrilege to cast callously to the dogs the bodies even of the very lowest of those who, through the sacrament of baptism, had been enrolled among the ranks of the redeemed.

But if paganism had no burial precedents toward which a Christian would feel himself strongly attracted, it was otherwise with Judaism, from whose bosom it must be remembered that Christianity had sprung. From the days of Augustus the Roman Jews had possessed subterranean cemeteries of their own beyond the walls, and nothing could be more natural than that Jewish Christianity in the capital should adhere to the mode of interment to which Judaism had been there accustomed. Stronger, too, than even any associations with national usage, would be the profound feeling of reverence for the example which had been rendered sacred in the entombment of Christ Himself. The hills outside Rome did not, it is true, in their nature resemble the limestone hills of Judæa, whose sides were everywhere perforated with cave-tombs, whether for individual or for family use, "as the manner of the Jews is to bury" (John xix. 40). But in lieu of limestone, most of the country round the walls had its own characteristic tufa formation, which was even better suited for purposes of inhumation, and there the faithful servants of their Lord might be laid to rest, even as long years ago in Jerusalem He had Himself been laid in the rock-hewn sepulcher of Joseph's garden.

Easily accessible from all parts of Rome, the undulations of the neighboring Campagna rose and fell in a series of pigmy hills and depressions whose soil was of volcanic origin. Differing in the dates of their deposit, the strata differed also in character. There was the red rock, the "lapis ruber," to whose durability for building purposes the ancient Cloaca Maxima could bear witness, but which defied the crude manipulations of pick and spade. There were also the loose sandy beds of the "arena," or "pozzolana," as it is now called, admirable for cement or mortar, but too crumbling and incoherent for structural stability. Mingling itself with these there was yet another deposit of igneous rock neither so hard as the one nor so soft as the other, but of just sufficient compactness and consistency to make it safely workable. It was in this intermediate formation, this "tufa granolare," that nature seemed to be offering the very material which the Christians needed, and it is accordingly in this layer of the volcanic rock that the greater number of the catacombs have been hollowed out. Porous in its structure, water drains off it with so much rapidity that inasmuch as the cemeteries did not extend to the intervening valleys, but were, as a rule, confined to the high ground of the hills, the risk of inundation was rendered inappreciable and the various galleries and chambers were kept sufficiently dry.

Thus it was that the venerated tradition of their Master's grave in the rock, the influence of Jewish custom, the law of the land, and considerations of ordinary convenience, all combined to determine for the primitive Christianity of Rome the character of its burial-grounds. Situated outside the Servian walls, as the authorities prescribed, these privately owned foundations came under the strict guardianship of the Roman College of Pontiffs who would find in them nothing to call for their official interference. Here, therefore, the solemn rites of religion would neither be insulted by contact with the idolatries of the heathen population nor disturbed by the indecent mockeries of the profane. . . .

Constructed in days of religious peace, the entrances to these earliest excavations stood by the roadside, open and unconcealed, so that no passer-by could fail to see them, nor was there at first any trace of those precautions against a sudden surprise which became a vital necessity in the dark days of the third century. No uniform type of internal arrangement and structure was adopted, since the design would naturally differ in each case with the wishes and wealth of the founder and with the character of the ground. Though locally distinct in their original sites, there was nothing to prevent the interlinking of adjoining cemeteries, provided only that they lay on the same hillside, by means of subterranean communications. Indeed, in

RELICS IN THE POZZI COLLECTION.

* Extracts from a paper by Mr. H. W. Hoare, in The Nineteenth Century.

point of fact, as the Christians increased in numbers, it was in this manner that their burial-grounds tended to expand, the insuperable bar to any general unification being the marshy soil of the intervening valleys. . . .

When a suitable plot on one of the hillocks of the Campagna had been conveyed, as we might now say, in trust for a cemetery, the land as defined by its legal boundaries became what was technically known as a "locus religiosus," a plan of which would probably be filed among the city archives. This plot was thenceforth invested with certain jealously guarded privileges. Not the least important of these privileges was that in the event of a sale of the grantor's estate the burial area did not pass with the remainder of the property, but continued to be at the disposal of the founder's family and of those outside it to whom the family rights might be extended. The work of excavation would usually be begun by digging out a short staircase from the surface to the depth selected for the first level, which in most cases might be a few feet below the upper soil. Along this level, from end to end, a horizontal tunnel or narrow passage was carried, in width from two to three feet, and perhaps some eight feet or so in height, with either a flat or a slightly vaulted roof. Then, at right angles to the passage, a second gallery of similar character was constructed and continued up to the boundary. All subsequent workings on this level would be governed by these two main determining lines, which recalled the methods of Roman civil engineering and corresponded to the well-known "cardo" and "decumanus" in the plan of an encampment or of a new town.

In the vertical walls forming either side of the passage, the "fossores," or sextons, next proceeded to carve out a series of recesses, each large enough to hold one or more bodies. These were called "loci," or, less properly, "loculi," and constituted the ordinary graves which, in any completed series, closely resemble those tiers or ranges of sleeping-berths so familiar to us on board our ocean steamers. With a view, moreover, to the disposal of the bodies with the greatest possible reverence, these niches were cut parallel with the gallery, and not, as in other than Christian catacombs, at right angles to it. Coffins were not ordinarily used, and it was necessary, therefore, with a view to guarding against the products of decomposition and providing safe access to the graves, whether for prayer or for other equally solemn purposes, that the recess should be hermetically sealed up as soon as the body had been deposited. This was done either by means of a slab or by tiles, and it is curious to observe that some slabs have been used twice over, the inscription on their inner side being of a pagan and that on the gallery side of a Christian character.

As the demand for space grew greater with the ever-increasing number of converts, either cross-galleries were added, or possibly the floor of the level was lowered so as to expose more rock, to the right and left, for supplemental graves. But when the resources of one level had been exhausted further provision could only be made by sinking a new level lower down, since the available superficial area was strictly limited to the space between the legal boundaries of the property. In such an event great care was taken that the successive levels should be excavated at such intervals as to be separated by a mass of unworked soil of a sufficient density to secure adequate stability for the new passages and recesses. The usual number of such distinct and separate levels or floors is from two to three, but in a few cases as many as five occur, and in one instance (that of the catacomb of Callistus) even seven. Communication between one level and another was provided by stairs cut out of the rock, and long shafts in connection with the open air were made to convey the requisite minimum of light and ventilation.

It was in some such manner as we have attempted to depict that without let or hindrance from Rome the catacombs appear to have been constructed by their originators. But with the fifth decade of the third century there came a grave crisis in the history of the Church. The Empire was at length fully awake to the imminence of the danger by which it was being threatened, and under Decius in the year 250 A. D. persecution began its work anew. . . .

The external history of what may from this period be called the burial-grounds of the Church has much in it of interest, but we must here dismiss it with only a brief glance. In A. D. 257 the emperor Valerian "forbade all assemblies of Christians, and all visits to *the places called cemeteries*." . . .

It is accordingly to these years of terror that certain very remarkable alterations in the catacombs must be referred. In order, if possible, to baffle pursuit, the officers in charge set to work radically to revise their structural arrangements. Aware, no doubt, that their ground-plans lay open to public inspection in the offices of the College of Pontiffs, these resourceful engineers blocked up or obliterated the known entrances, and dug out new circuitous rambling conduits which eventually emerged in some disused and therefore unfamiliar sand quarry. This done, they proceeded to demolish large portions of the existing staircases, so that no one could use them without ladders, substituting others in changed positions, while at the same time by filling up many of the galleries with earth they rendered the approaches to the most venerated and frequented sepulchres all but inaccessible. . . .

With the sack of Rome by Alaric in A. D. 410 began the long series of invasions by the barbarian hordes, and the Campagna, which was often the actual scene of their encampments, became better suited to the armed plunderer than to the peaceful worshiper. In spite of all the labors of successive Popes, the old reverence for the catacombs began now gradually to fade away. The material treasures of wealth which they were believed to conceal, as well as their inexhaustible store of religious relics, had made them the hunting-ground of innumerable robbers, and their custodians accordingly endeavored to preserve all that remained worth preserving by translation to the crypts of the city churches. By the middle of the ninth century this tedious and melancholy work had been completed, all interest in the catacombs had ceased, and they soon became so utterly neglected that in a few more years they had altogether passed out of human memory.

[Concluded from SUPPLEMENT No. 1564, page 25061.]

THEORIES OF ORE DEPOSITION HISTORICALLY CONSIDERED.*

By S. F. EMMONS.

The Verification Period.

THE third period, covering in a general way the last quarter of the past century, may be called the period of verification. So fertile had been the imagination of previous thinkers on this subject that at this time it was practically impossible to conceive a theory of origin for a given ore deposit that had not already been proposed or at least suggested. The investigations now to be carried on with more perfect methods, or in the light of recent advances in the science, would seem more properly verifications of old theories than the propounding of new ones.

Method and the microscope have been the two great agents of progress. The greatest improvement in method has resulted from government aid, under which it has been possible for organized bodies of scientific workers to make special examinations of entire mining districts, and thus determine all the facts bearing upon ore deposition in those districts with an exhaustiveness that was impracticable for the unaided individual observer. The newly created science of microscopical petrography, through the intimate knowledge it has afforded of the internal structure of rocks and ores, has admitted so accurate a determination of the processes by which they have been formed that much that was formerly mere conjecture has become established on basis of fact. America, which hitherto had occupied a very subordinate position, had come to the front, not only in the production of metallic ores, but in its correct understanding of the processes by which they were formed.

In order to properly appreciate the progress which has been made during this period, one must endeavor to realize the mental standpoint of the average student at the close of the preceding period.

To the miner and prospector, whose opinions carry weight because of their wide practical experience, a typical ore deposit was a vein which, once an open crack extending to an indefinite depth, had been filled by material introduced in one way or another from below, and the more nearly a deposit approached this typical form, the greater its value. Indeed, for a time some of the most valuable deposits in the West were entirely neglected by the prospector because they did not possess the physical characteristics of the "true fissure vein." This misconception arose from the fact that this, being the most clearly defined form of deposit, had been the only one mentioned in early speculations, and that hitherto the classification of text-books, based as they were on the almost accidental characteristic of form, relegated other types of deposit to a distinct and relatively subordinate class, disregarding the fact that this class includes many of the largest and most productive ore bodies, which may not only have the same origin, but often be associated in the same deposit with a typical fissure vein.

Von Groddeck (on the other hand), who represents the most advanced scientific opinions of his time (1879), divides ore deposits into two classes:

1. Those formed contemporaneously with the inclosing rock, whether (*a*) sedimentary or (*b*) eruptive.
2. Those of later formation classed under two heads:
   (*a*) Those filling pre-existing open spaces.
   (*b*) Metamorphic deposits formed by alteration of rock in place.

His two main divisions corresponded to a certain extent with those made in 1854 by J. D. Whitney (Metallic Wealth of the United States), namely, stratified and unstratified. One difference is that metamorphic deposits were included by Whitney in the first division and by Von Groddeck in his second. Neither recognized their true importance, and the latter, while admitting that he included in this class those that Stelzner had called metasomatic deposits, said they could not be regarded as separate deposits, because they are only incidental phenomena of the filling of cavities.

As a means of obtaining a clear view of the whole field, Von Groddeck divided known deposits into types (54 in number), characterized in the main by their varying mineralogical and lithological associations. Of these, 16 belong to his first subdivision, 5 to the second, 26 to the third, and 7 in part to the third and fourth, a classification which he admitted must be considered but tentative, owing to defects in existing knowledge which could be remedied only when all mines could be studied on a monographic or exhaustive system.

In America, though apparently unknown to Von Groddeck, such monographic studies had already been made—that of the Comstock lode by King (Fortieth Parallel reports, 1870), of the Lake Superior copper deposits by Pumpelly (Michigan geological survey, 1873), and that of the lead deposits of the Mississippi Valley by Chamberlin (Wisconsin geological survey, 1873-1879). These were followed in the early eighties by reports on the Comstock lode by Becker, on Leadville by Emmons, on Eureka by Curtis, and on the copper-bearing rocks of Lake Superior by Irving—monographic studies which constituted an important feature in the plan of work laid out for the newly established United States Geological Survey. It was the expectation of those who planned this work that when all the important mining districts of the United States had been thus exhaustively studied, a sufficient store of well-ascertained facts regarding ore deposits would have been accumulated to admit of the formulation of a new theory more firmly grounded on a basis of well-established fact than any that had yet been presented.

It may be said of the deposits studied in the first decade of the survey work that, in the form in which they were found, they were all determined to have been deposited from aqueous solutions and to be of later origin than the inclosing rocks. The lead and zinc ores of the Mississippi Valley might have been included in Von Groddeck's contemporaneous class if, as assumed by Whitney and Chamberlin, these metals had been deposited with the limestones at the time of their formation; but while, as to this ultimate source there is some difference of opinion, all are agreed that the concentrations which produced the workable ore bodies were of later date; hence it seems more logical to consider them of later formation than the inclosing rocks.

In the case of the other deposits studied, which were found to occur either in or in the immediate vicinity of eruptive rocks, it was assumed that the percolating waters had derived their metallic contents from some of these eruptive rocks, which careful tests had shown to contain small amounts of the various materials of the deposits. This derivation had an advantage over that of indefinite depth appealed to by the ascensionist or hydrothermal school, inasmuch as it admitted some sort of experimental proof, indirect though it was, and because at the depth at which the rocks might be supposed to be essentially richer in metals than those found at the surface, cracks sufficiently open to admit a free flow of thermal waters were considered impossible under the conditions of pressure assumed to exist there. This view was called a lateral-secretion theory, though it differed essentially from that of Sandberger, in that the derivation of the vein minerals was not restricted to the immediate wall rocks (Nebengesteine) of the deposits. Indeed, in a later discussion it was characterized as another form of the ascension theory. The circulating waters which had brought in the vein materials were assumed, though not always explicitly, to be of meteoric origin—waters which originally descending from the surface had become heated either in contact with igneous rocks or by the internal heat of the earth, and gathering up mineral matter in their journey had redeposited it when conditions favored precipitation rather than solution. The natural channels through which these waters would circulate most freely, and which hence were most favorable to ore deposition, were rock fractures produced by dynamic movements in the crust; faults or joints to which Daubrée had given the designation "lithoclases." In no case were these fractures found to be contraction fissures, which Werner and many subsequent writers assumed to be the typical vein fissure, disregarding the consideration that contraction fissures could not traverse two distinct bodies of rock. To the joint-like fissures that are confined to a single bed, Whitney had already given the name "gash" veins.

In the Comstock Lode report, Becker had discussed mathematically the mechanics of faulting as applied to vein fissures, and had shown that an important characteristic of faulting on a fissure in solid rock is the tendency of the movement to separate the rock into sheets by subordinate fissures parallel to the main one. From practical observation Emmons had similarly concluded that the faulting movement which produced vein fissures was often distributed on a number of parallel fissures, thus producing a sheeting of the country rock. Where these fissures were sufficiently close together so that the intermediate sheets of country rock were very thin and had been partially replaced by vein material, a banding would result which might be mistaken for that of the typical vein of incrustation. Where they were farther apart and of approximately equal strength, the mineral filling, instead of being confined to a single fissure, might be distributed on several, thus rendering frequent crosscutting advisable in their exploitation.

The idea that later-formed ore deposits are necessarily the filling of considerable cavities or open spaces in the inclosing rocks has been considerably modified by the important rôle that the process of metasomatic replacement or substitution has been shown to have played in the formation of ore bodies. The idea of replacement had been suggested in the conversion theories of the early speculators and more distinctly expressed by Charpentier. By the geologists of the second period it was comparatively neglected, though in a few cases admitted as a subordinate factor, especially in the formation of deposits in limestone. Even in Posepny's frequently quoted studies of the lead and zinc deposits of Raibl in Carinthia (1873), he admits this mode of formation only for the oxidized ores, considering the sulphide ores to have been deposited in open cavities.

In America Pumpelly first applied this process to the copper deposits of the Lake Superior region (1871), of which he says: "In at least very many instances, if not in all, the deposition of the copper is the result of a process of displacement of pre-existing minerals."

Leadville and Eureka were the first large mining

* Annual address by the president of the Geological Society of America, read before the society at St. Louis, Mo.

districts in which it was proved that extensive ore deposits were entirely formed by metasomatic replacement of the inclosing rock, which in these cases was limestone. Later observations showed that this form of deposit was not confined to limestones, and that in fissure vein deposits, even in acid rocks, metasomatic processes had often played an important part in replacing by ore portions of the country rock which, under the old views, might have been regarded as vein filling. The interest and importance of this view were speedily recognized, especially by American geologists and mining engineers, and while still novel, it was doubtless sometimes applied without sufficient proof as an explanation of the formation of certain vein deposits to the exclusion of that of the filling of cavities or interstitial spaces. With the general introduction of the microscope into the study of vein materials, however, a comparatively sure method was provided of distinguishing the results of the two processes. The process of verification has in this case resulted in the establishment of the importance and increasingly wide applicability of the metasomatic theory to the formation of ore deposits of all types.

In the latter part of the decade Irving and Van Hise's studies of the iron deposits of the Lake Superior region had demonstrated that they had been deposited from solution in descending or meteoric waters, whose downward course had been arrested by some impervious basement—sometimes a dike, sometimes a bed in a synclinal basin—and that during this time of stagnation their load of iron oxide had been laid down as a metasomatic replacement of the inclosing rock, a descensionist theory, but of essentially modern type.

In 1893 appeared the well-known paper, "The Genesis of Ore Deposits," by Posepny, for ten years professor of this branch of the science at the School of Mines in Pribram, Bohemia. Although Posepny's views were by no means universally accepted by geologists, especially in America, all agreed that his work constituted a most valuable contribution to the science by its clear definitions of the questions involved and their masterly scientific discussion. The great majority of ore deposits Posepny considered to be of later origin than the inclosing rocks, even those that are found in stratified rocks in apparent conformity with the bedding. Further, that they have been deposited by precipitation from waters of the deep circulation below the ground-water level. The ground water he conceived descends by capillarity through rock interstices over large areas, to rise again at a few points through open channels under the influence of heat. It derives its mineral matter from the barysphere, or deep region, where the rocks are richer in metallic minerals than near the surface, and subsequently deposits them in open spaces as it ascends. These spaces are either spaces of discission (rock fractures) or spaces of solution, the latter sometimes being formed by ascending thermal waters, even where no previous crack exists.

Fresh as he was from his controversy with Sandberger over the lateral-secretion theory, which he had disproved, at least in its application to the Pribram deposits, he was inclined to view with disfavor anything that flavored of lateral secretion; hence, while admitting that the presence of minute quantities of the metals in eruptive rocks leads to the surmise that they had brought the whole series of heavy metals up from the barysphere into the lithosphere or upper crust, he preferred to assume, in the cases which the American geologists had explained as derivation from eruptive rocks in the vicinity of the deposits, that the mineral contents had been brought up by thermal waters directly from the barysphere. Likewise, in the limestone deposits, which their studies show to have been formed by metasomatic replacement, he thought that they must have overlooked some evidence of crustification, and still held to the opinion that such extensive deposits must be mainly the filling of open spaces. Although not explicitly stated, it is evident that he regarded the water of his deep circulation as mainly of meteoric origin.

Of great practical value was the clear idea conveyed to the mind of his readers of the distinction between the oxidized or altered minerals and the original or sulphide minerals of an ore deposit, a distinction previously pointed out, though less emphatically, by Emmons* and others.

In the same year appeared the first of a series of important articles on the formation of ore deposits by the Norwegian geologist, J. H. L. Vogt, in which, as opposed to Posepny's views, so much more importance is given to igneous agencies that their different standpoints recall the antagonisms of the old Neptunist and Plutonic schools. The petrographic studies of Vogt and Brögger had disclosed in basic dikes a tendency of the heavier minerals to concentrate near the borders. Following out the suggestion offered by this observation, Vogt had proved by field study that certain titaniferous iron ores were actual segregations in the eruptive magma previous to its final consolidation. Based on petrographic studies made by Brögger and himself, and personal observations on ore deposits, principally in Norway, Vogt defined two methods of formation of ore deposits as the direct result of igneous action:

1. By magmatic segregation.
2. By eruptive after-action of pneumatolysis (a term first used by Bunsen to describe the combined action of gases and water).

In the first class (of admittedly infrequent occurrence) are titaniferous iron ores, chromite, and other metallic segregations in basic eruptive rocks. In the second class, commencing with tin and apatite veins, he included, as time went on, increasingly numerous types of deposits. This was in one sense a revival of de Beaumont's theories, but the modern standpoint differed in that the existence of a liquid molten interior of the earth had been disproved by terrestrial physicists. Vogt held that as no communication could be established between ore deposits and a heavy interior, they must have been derived from a crust, say 10, 25, or 50 kilometers in thickness, and in great measure the result of eruptive processes within that crust.

Emmons (in 1893) acknowledged the importance of the magmatic concentrations of metals in eruptive rock, but thought that in most cases such accumulations must have been further concentrated in order to produce economically valuable ore deposits.

During the second decade the influence of Posepny's paper was felt in an increased adherence among outside geologists and mining engineers to the ascension theory. Vogt's views received less attention in this country, because for a long time no ore deposits were studied to which they were found to be applicable. The first case was that of the titaniferous magnetites of the Adirondacks studied by Kemp, who published his results in 1898.

The year 1900 was rendered important in the progress of theoretical views on ore deposition by the simultaneous appearance of Principles Controlling Deposition of Ores, by Van Hise; Secondary Enrichment, by Emmons and Weed, and Metasomatic Processes, by Lindgren, and by the discussions which they prompted.

Van Hise's article was a broad, philosophic treatment, based on experimental data, of the whole question of underground circulation as bearing on ore deposition. It would be impracticable to give here any complete abstract of his paper, which is probably familiar to most of you, and only a brief statement of such points as bear on the general processes heretofore alluded to will be attempted. His discussion is practically confined to ore bodies deposited from aqueous solutions, which, he considers, embrace the larger proportion of workable deposits, and he holds that the waters from which these deposits have been made are chiefly of meteoric origin. Their circulation is in part descending, in part lateral moving, and in part ascending, and during each of these movements they may take up or deposit metallic minerals according as conditions favor either action. This circulation takes place in openings in rocks, mostly produced by fracture, and hence is confined to the outer portion of the crust, which he has defined as a zone of fracture as distinguished from a deeper zone, that of flowage, where, under accumulated pressure, deformation produces no macroscopic openings. Its general tendency is to concentrate from the small openings into larger or trunk channels. The deposits from these waters are distinguished as concentrations (1) from ascending waters alone; (2) from descending waters alone, and (3) first from ascending and second from descending waters. In prevailing composition the first class are sulphides, tellurides, etc.; the second oxides or oxide salts, while the third are chiefly the one or the other, according as they were formed above or below the ground-water level.

Emmons and Weed, coming to the subject from a different but somewhat narrower standpoint—that of a practical field study, extending over several years—explained the frequent occurrence of bonanzas, or exceptionally rich portions of deposits just below the oxidized zone or ground-water level, as the result of leaching by surface waters of the upper portions of these deposits and their redeposition as sulphides in contact with pre-existing metallic sulphides (especially pyrite) in the zone below. Through similar processes of chemical reasoning and with a similar disregard of Posepny's assumption that the ground-water level forms an effective barrier separating the action of the surface or vadose waters from that of the deep circulation, all three arrived at the same general conclusion with regard to the continuance of rich ore in depth, a question which has occupied the attention of geologists and miners since the days of Werner. This conclusion was that in most ore deposits a deeper region exists beyond the influence of surface waters in which the ore is of comparatively low and uniform grade. Van Hise even went so far as to say that in depth all deposits would become low-grade pyritic ores, and that all veins would eventually wedge out.

De Launay, in his generalizations on Mexican deposits, had already recognized three zones: (1) an upper oxidized zone, (2) a middle zone of rich sulphides, and (3) a lower zone of low-grade sulphides. He assumed the enrichment of the middle zone had been by descending waters, but placed it above the ground-water or hydrostatic level, which in many veins had probably been displaced since their original formation.

In his article "On metasomatic processes in fissure veins," Lindgren placed this theory for the first time on a scientific basis of chemical and microscopical study, and by a classification of veins according to the predominant metasomatic mineral or process involved he made its application much clearer to the student and observer. In his closing remarks he suggested that of late sufficient attention had not been given to the French theory of emanations from eruptive magmas, and that in the case of metals with low critical temperature they may have first been carried up under pneumatolytic conditions and with the aid of mineralizers while still above the critical temperature, until they reached the zone of circulating atmospheric waters.

His paper "On contact deposits," 1901, following out this suggestion, served a useful genetic purpose by calling attention to and clearly defining a group of deposits for which a pneumatolytic origin would readily be admitted, but of which no important examples had yet been studied in America. The term "contact deposits," which had hitherto been loosely applied to all deposits, without regard to origin, which happened to lie near the contact of any two bodies of rock, was restricted by his definition to those occurring near the contact of igneous intrusives with calcareous beds. They are characterized by irregularity of form, the association of iron oxide and sulphides of the metals with various lime silicates, generally called "contact" minerals because they are found to be the result of contact metamorphism. Typical developments of these contact minerals near Christiania in Norway, in the Banat in Servia, in Tyrol, Italy, and elsewhere had been the subject of repeated study and discussion among European geologists since the middle of the century, but the metallic deposits connected with them being generally of subordinate economic importance had, up to the time of Vogt, not been considered worthy of a distinct place in the classification of ore deposits.

The importance of pneumatolysis in forming ore deposits was emphasized by the discovery on this continent, soon after the publication of Lindgren's paper, of a number of economically important deposits, especially of copper, which would come within his definition of contact deposits.

From a more theoretical point of view the contemporaneous paper of Kemp, "The rôle of igneous rocks in the formation of veins," presented a more decided opposition to the view so emphatically voiced by Van Hise, that the majority of our ore deposits have been formed by precipitation from circulating waters of original meteoric origin. In this Kemp maintains that ground-water circulation is not sufficient to account for the majority of ore deposits, but that igneous rocks must have furnished not only their metallic contents, but a large, if not predominating, proportion of the waters which brought them into their present position.

The controversy which had thus arisen as to the relative importance in the formation of ore deposits of waters of meteoric or of igneous origin has more recently received a further impulse in the discussions provoked by the presentation of proposed genetic classifications of ore deposits by W. H. Weed and J. E. Spurr. These geologists took an even more advanced position than Vogt in regard to the direct influence of igneous agencies in the formation of ore deposits, adding siliceous segregations to his class of magmatic differentiation products and very greatly enlarging the scope of his pneumatolytic class. The influence of these new views is already seen in the current literature on ore deposits, especially in articles where the author, though not in possession of full data, still feels it incumbent upon him to present some tentative hypothesis of origin for the deposits which he is describing.

RESULTS ACHIEVED.

The wide divergence of views shown by these discussions to be held by recognized authorities on the subject might lead one to conclude that we are as far as ever from a universal agreement on accepted theories. A more deliberate consideration of the progress of investigation and verification during this last period, which has been but too briefly and imperfectly set forth in the preceding pages, will show, however, that the advance in this direction has been real and permanent as far as regards the later stages of ore formation, which are more susceptible of actual proof, and that the disagreement lies rather with the ultimate or more theoretical sources of derivation, which must always remain to some extent matters of opinion.

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* Colorado Scientific Society, vol. ii, pt. ii, 1886, p. 99.

The invention of the incandescent lamp of Edison has given medicine some instruments which are quite indispensable. Even before the carbon filament was invented the importance of the electric lamp for purposes of medical diagnosis had been realized. Nitsche used tiny loops of platinum wire in his early cystoscopes, and although he experienced endless vexations through the fusion of the wire filaments, so that it is said that his lamps required almost daily renewal at great expense, yet he was so convinced of the value of the electric exploring lamp in the field of bladder surgery as to persevere in the face of all difficulties until the invention of the carbon filament provided him with a satisfactory solution of the problem. Numerous lamp instruments are now used by surgeons, but it is only necessary to specify two of them—the cystoscope and the Antrum lamp—to show that here, too, electricity has rendered good service.

INSECT PAPER MAKERS.

HOW DECAYED WOOD IS CHEWED AND CONVERTED INTO PULP. DETAILS OF THE HORNET'S METHOD OF MAKING PAPER.

By HENRI COUPIN.

WASPS make their nests of paper, which they manufacture by macerating decayed wood with their mouths. The pulp thus obtained, when formed into thin sheets and allowed to dry, yields a product very similar to coarse wrapping paper. The details of the process have recently been studied by Janet, some results of whose observations are given herewith.

The nests are suspended from branches of trees,

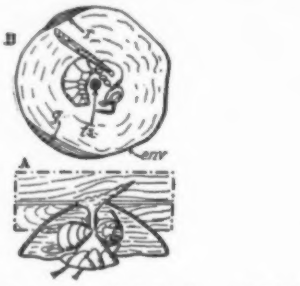

Fig. 1.—Horizontal and Vertical Sections of Nest in Eleventh Day of Construction, with Queen Curled About Tube and Resting on Comb.

beams and eaves of buildings, and roofs of underground cavities. They are composed of masses of hexagonal paper cells arranged in several horizontal combs and surrounded by one or more protective envelopes of the same material which are at first distinct but finally consolidated by a tangle of transverse sheets.

The species of wasp known as the hornet makes its paper chiefly of half decayed wood as is proved by the appearance of the nest, observation of the insects at work, and microscopic examination of the pulp which they bring home, but it also uses moss and other substances. A worker flies from the nest and returns in from two to six minutes with a ball of pulp about a quarter of an inch in diameter, which she invariably elaborates and applies herself, though food thus brought home is often turned over to others. Clinging to the comb with the claws of her middle and hind feet, she holds the ball of pulp with her fore feet and legs and keeps it in continual rotation while she chews it vigorously with her mandibles. In about a minute the coarse pulp has been ground and salivated to the desired consistence. Then the insect seeks a place in which to utilize the prepared pulp.

Usually she employs the first portions in building additions to the protective envelopes. For this purpose she installs herself on the edge of the unfinished sheet with her abdomen within the envelope and with her three right feet inside and her three left feet outside, or conversely. The ball of pulp is held between the lower surface of the mandibles and the upper surface of the thighs of the first pair of limbs, and barely touches the edge of the envelope to which it is to contribute an addition (Fig. 5). Then the mandibles open slightly and the soft pulp fills the narrow fissure between them. The insect moves backward, dragging the ball along by an alternating movement of the mandibles from the position *a* to the position *b* and leaving a narrow strip of new paper attached to the envelope.

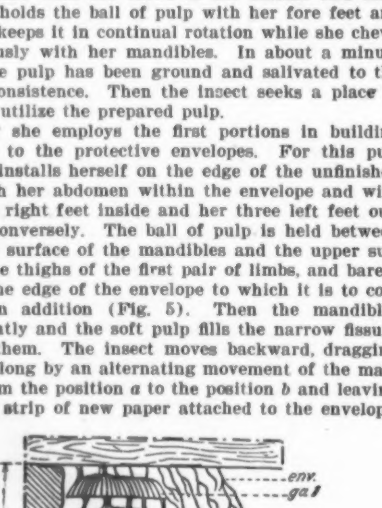

Fig. 2.—Section of Large Nest Containing Twelve Combs.

When the ball has become very small it is held entirely by the jaws and lip, without touching the legs. As the little strip of paper is deposited the mandibles shape it and cause it to adhere to the sheet to which it is added. During the entire operation the insect incessantly strikes the line of junction with her right and left antennæ, alternately.

The new strip is about a sixteenth of an inch wide. When it has been extended to a length of from half an inch to an inch and a half, the insect returns nearly, but not quite, to the point of beginning and deposits a second strip, and then a third. (Fig. 1, *B.*)

When the first envelope has reached the level of the first comb, the queen of the colony performs a remarkable operation. Carrying a ball of pulp, she bestrides the edge of the envelope in the manner of a worker, except that her left hind leg is extended to its full length and its claws are fastened on a central cell of the comb. The leg thus forms a radius of a circle in which the queen moves as she deposits her paper ribbon. In this way is established the regular form of the envelope which is, normally, a surface of revolution.

The queen usually consumes five minutes in depositing a ball of pulp. The workers accomplish the task in two or three minutes.

The hornet often interrupts her work on the envel-

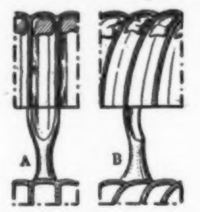

Fig. 3.—Tube Attached Above to a Single Cell. (Partly Cut Away to Show Cavity.)

opes and employs the last part of her ball of pulp, after a second prolonged maceration, in cell building, though entire balls of very fine pulp are also used for this purpose. The operation is similar to the one above described but it is performed with greater care and the paper is thinner. The consumption of an entire ball of pulp in building cell partitions occupies six or eight minutes, though two minutes often suffice for the addition of an equal quantity to the envelopes.

While the new additions to the cell walls are still

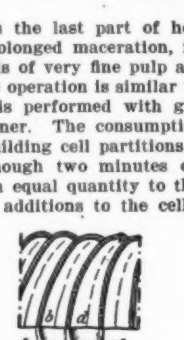

Fig. 4.—Tube with Several Cavities Attached to as Many Cells.

moist and soft they are subjected to many retouchings. The insect almost always goes over her work before leaving it and often returns to it once or twice. Both queens and workers are frequently seen to stop and retouch the soft, new constructions upon which others are engaged. In times of great activity, indeed, these retouchings are necessary in order to repair damages accidentally caused by the hurried passage of many insects. The new paper is liable to deformation until it has become quite dry.

The individual worker brings home pulp of the same color for several days in succession but, as the material furnished on the same day by different workers may differ greatly in tint, the completed nest presents a more or less striped and variegated appearance.

The paper of which the cells and envelopes are formed is very weak and easily torn, so that it appears surprising that large nests, like the one with twelve

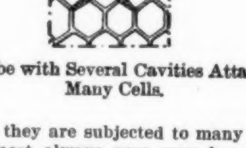

Fig. 5.—Front and Side Views of Hornet Building Envelope.

combs shown in Fig. 2, can sustain the weight of the masses of larvæ and pupæ which fill them. In a nest studied by M. Janet, a comb a foot in diameter was suspended from the comb above it by a central paper tube one-third of an inch in diameter and eighteen smaller auxiliary tubes of irregular cross section. The upper surface of the comb is covered, especially about the central suspension tube, with a glossy varnish furnished by a gland situated in the lip of the insect. This coating adds greatly to the strength and stiffness of the sheet of thick paper composed of the bases of the cells, properties which are especially useful at the points of attachment of the auxiliary tubes.

These tubes are also strengthened in a curious way. The broken lids of used cells, reduced to pulp and mixed with the adhesive salivary fluid, form a sort of felt composed of strong silken fibers. Most of the suspension tubes are covered, partially or entirely, with this material which is attached, above, to the cells of the upper comb and expanded, below, about the insertion of the tube. The reinforcement is precisely similar to that obtained by covering a paper tube with muslin. This silk pulp is found also on the upper surface of the comb, in spots which had perhaps been selected as the points of attachment of additional suspending tubes.

Below, these tubes have a solid base of attachment in the bottoms of the cells of the suspended comb, but above they can be fastened only to the edges of cells. For this reason they expand above into stellate forms in order to attach themselves to a number of cell walls, the strength of which is increased by the silky coat which clothes them.

One of the secondary tubes, one-fifth of an inch in diameter and partly covered with silk, on being subjected to gradually increasing tension, broke in the middle with a weight of 5.5 pounds. This corresponds to an ultimate tensile strength of 150 pounds per square inch. Eighteen such tubes would support a weight of nearly 100 pounds. The weak point of this method of suspension, in fact, is not in the tubes themselves but in the attachment of their bases to the bottoms of the cells, which under unevenly distributed stresses are liable to be torn off, one by one. The regular circular form of the combs and the symmetrical distribution of the loads borne by them are, therefore, two of the chief conditions of stability.—Abstracted for the SCIENTIFIC AMERICAN SUPPLEMENT from La Science au XXme Siècle.

SCIENCE NOTES.

Recently the effects of temperature on photosynthesis have been carefully worked out by Miss Matthaei. She states that the curve of synthetic activity rises with increased temperature, that it is in general convex to the temperature abscissæ and somewhat similar to the curve of relation between temperature and respiration. There is a certain maximum for each temperature. It has also been ascertained that there is a certain economic light intensity beyond which there is no increased photosynthetic activity, and doubtless only injury. This is of special interest in connection with some recent work by Weis. Recognizing the fact that plants are of very different types with relation to their light requirements, he has sought to get an expression of their assimilatory energy. He finds that *Œnothera biennis*, a well-marked sun plant, fixes under favorable conditions of temperature, and in direct sunlight, about three times as much CO_2 as in diffuse light (light of one-sixtieth to one-ninetieth this intensity). On the other hand, *Polypodium vulgare* assimilates in diffuse light somewhat more energetically than in direct, while *Marchantia polymorpha* occupies a position intermediate. This will be welcomed by physiologists as a field for wholesome ecological study, for an extension of such investigations to an analysis of plant associations with relation to the light factor may yield profitable results.

The remarkable properties found by Madame Curie in the preparation containing polonium have also been observed by Prof. Marckwald and his assistants in certain substances prepared somewhat differently which are designated in Germany under the name of radio-tellurium. According to Marckwald's hypothesis, the new radioactive body fills the place which has been empty in the periodic series of the elements in the sulphur column, not far from bismuth. As to whether radio-tellurium is distinct from polonium there seems to be no reason for supposing such to be the case and the arguments which have been brought in favor of such an idea seem to show only one point, that the polonium of Mme. Curie is not a definite body, and seems to be mixed with numerous impurities which give it variable properties, while the radio-tellurium of Marckwald acts like pure polonium. Mme. Curie mentions some chemical properties which allow us, if not to isolate polonium, at least to separate it from bismuth and most other elements by fractionating. Marckwald's radio-tellurium has better-defined chemical reaction and it can be isolated more completely. It seems that polonium plays the part of a radioactive element, like radium. During the first period of the researches, this point seemed to be doubted, for according to Mme. Curie's observations, polonium loses gradually its active properties and moreover its radiation consists entirely of α-rays. But since then we learn, especially by Rutherford's researches, that all the active bodies become destroyed gradually and the only difference between them lies in the duration of such destruction. Again, Rutherford showed that the emission of α-rays seems to be the only primitive one, and that the β and γ radiations only appear after a transformation of the body. Nothing prevents us from considering polonium as a radioactive body, and in order to confirm this conclusion it only remains to find a well-defined "constant of transformation" for it. We know that a constant of this kind goes to characterize a radioactive element as clearly as a spectral ray or an atomic weight. However, Marckwald shows that the numbers published by Mme. Curie do not allow us to give the polonium which she obtained a determined constant of this nature. As the laws of decrease were found to be variable according to the samples and the periods of experiment, we should conclude with the German physicist that she operated with complex bodies. But whether the essential element of this mixture is distinct from radio-tellurium it is not possible to affirm. The determination of the constant of the new body brings out an interesting fact. Marckwald, Greinacher and Herrmann made the determination independently. They found the curve which connects the radioactivity with the time. This curve takes the form of a straight line, whence we deduct that the radio-tellurium is a simple radioactive element, and we also find the numerical value of its "transformation constant." This figure is 0.00497, taking one day as a unity of time.

ENGINEERING NOTES.

In order to combat the excessive temperature which attends high compression in gas engines, certain makers, among whom we may mention the Nürnberger Maschinenbau Company, have provided the piston ends of their single-acting engines with a water circulation. This is effected by a pump forming part of the engine. This is evidently a complication which others have easily avoided for engines even of 150 horsepower, by arranging the piston so that a free access of air, due to the to and fro movement, alone effects the cooling. In order to derive every economical advantage from high compression without running the risk of self-ignition, the firm of Koerting has arranged inside the explosion chamber of their Otto cycle engines a hollow casting through which there is a special water circulation. This cooling effected in the very heart of the mixture deals with the excessive temperature there, and is said to have given the best economical results. In double-acting engines the cooling is still the object of great attention, and apart from the cylindrical jacket and cylinder ends, independent water circulation is used to cool the piston and piston-rods, the seats of the exhaust valves, and the stuffing-boxes. The general temperature of the surrounding parts is kept cooler than in English engines, and for this purpose water is delivered at certain parts, such as the piston and piston-rods, at pressures from 1 to 4 atmospheres (15 to 60 pounds) by means of a special pump.

It may be laid down as a good rule that it is more economical to use boilers of reasonably large size than to subdivide into a larger number of small units. The length and area of grate that can be conveniently fired or kept evenly covered with coal is, perhaps, the limiting feature, if hand-firing is to be used. Working from this rule, a grate should not be over 7 feet long or more than 5 feet wide, which would give 35 square feet of grate surface. The quantity of coal that may be burned on such a grate varies widely with the kind of fuel and strength of draft. Using bituminous slack coal of fair quality, with good natural draft or moderate induced draft, it should be possible to burn 25 pounds of coal per square foot of grate per hour, or 875 pounds of coal per hour; and if this coal will evaporate, say 8 pounds of water per pound of coal, the boiler, if constructed with heating surface in proper proportion, would evaporate 7,000 pounds of water per hour, which would be equal to a little over 200 standard boiler horse-power. In order to give good economy, the boiler should have from 2,000 square feet to 2,400 square feet of heating surface to evaporate this quantity of steam economically. The return tubular boiler, on account of the amount of tube surface in proportion to the direct surface exposed to the fire, should have not less than 12 square feet per horse-power; the water-tube type from 10 to 11; and the internally-fired type, which has a larger amount of direct-heating surface in the furnace and tubes than either of the others, should have 9 to 10. If this grate surface is larger than that described, probably the grate will not be evenly covered with coal, or the fire will be dead in spots, so that too much cold air will pass through.

It is a generally accepted fact that the steam locomotive has reached practically the ultimate size of its possible development. The weight per driving wheel is nearly at a maximum, as are the grate area, the heating surface and the steam pressure. It is also practically limited by the ability of one or two firemen to keep up steam, by the quantity of coal and water which may be carried in the tender, and, in size, by the bridge clearances. Perhaps it would be better to make some comparison between the steam locomotive and the electric locomotive rather than between the steam locomotive and motor cars, although for suburban service the latter comparison is undoubtedly the only fair one. From tests recently made in comparing the most powerfully built steam locomotives of the Atlantic four-drive and Pacific six-drive types, operated by the New York Central Railway Company, and electric locomotive No. 6000, built for passenger service on the main line in the New York Central tunnel, and to haul all through trains into the city, it was found that with the same weight on the drivers nearly 50 per cent higher acceleration could be obtained by the electric locomotive than by the steam locomotive with the same trailing weight, and that the electric locomotive could maintain a higher speed. Since acceleration is the limiting feature for frequent-stop service, and speed is the limiting feature for through-haul service, it is evident that this electric locomotive, with direct-current gearless motors, has a decided advantage as regards schedule over the steam locomotives now doing the work. While it is a fact that the speed curves of the direct-current motors show a great decrease in tractive effort with increase in speed, from actual tests this does not seem to limit the train speed to such an extent as the combined effects of steam throttling with short cutoff and back pressure due to exhausting at high piston speed on a steam locomotive. As to acceleration, the electric locomotive can keep up a practically uniform torque which will be at the slipping point of the wheels, up to a speed of thirty to thirty-five miles an hour, or as long as the locomotive is being accelerated on the resistance points of the controller. The steam locomotive can only exert its maximum torque at full steam pressure used for the full length of its stroke, and cannot be run up to a speed of more than ten or twelve miles an hour before it is necessary to cut off earlier in the stroke to prevent excessive decrease in boiler pressure. It will be seen then that the boiler capacity and not the engine capacity is the limiting feature of the steam locomotive.

SOME EXPANSION EXPERIMENTS.

M. Rémy has devised a series of very simple and inexpensive experiments to show the expansion of substances by heat. This expansion takes place in all directions. In general, a solid body occupies a greater volume when it is hot than when it is cold, and elongated bodies like bars, tubes, and wires, in particular, show an appreciable and progressive increase in length with elevation of temperature.

A copper wire, stretched by a small vise or other

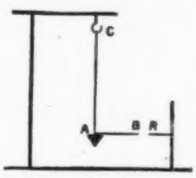

Fig. 1.—Expansion of Wire Observed Directly.

convenient weight, *A*, hangs from a hook, *C*, which is screwed into the horizontal arm of a wooden gallows (Fig. 1) or fastened to a long nail driven into the wall. The lower end, *AB*, of the wire is horizontal and points to a nail, *R*, or other mark on a vertical post. The effective length of the wire, *CA*, may be about five feet. Now, if the wire is heated by running the flame of a Bunsen burner quickly over it, its lower and horizontal portion will descend rapidly until it is very perceptibly lower than the mark, to which it will gradually return as the wire cools again to the temperature of the surrounding air.

In order to make the expansion more evident, by magnifying it on the principle of the lever pyrometer,

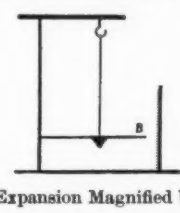

Fig. 2.—Expansion Magnified by a Lever.

it is only necessary to lay upon the weight, *A*, a perfectly straight aluminium wire, one end of which is inserted in a small hole in the vertical trunk of the gallows, while the other end is free to move over a vertical scale. (Fig. 2.) The end, *B*, will move in the same direction as the weight, but through a greater distance.

With this apparatus a very pretty experiment may be made by substituting an India-rubber tube for the wire. The weight should be just sufficient to stretch the tube to twice its original length. Then very slight warming will produce a deflection of several centimeters.

The unequal expansion of different metals can also be shown very simply. This is the principle of the

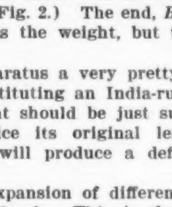

Fig. 3.—Difference of Expansion of Two Metals.

old Bregnet metallic thermometer. In the lecture room it is usually illustrated with the aid of a compound strip of iron and copper. But we need merely provide our wooden gallows with two hooks, an inch or less apart, and fasten to them a copper and an iron wire of the same length (about 5 feet) and thickness. (Fig. 3.) The wires are weighted at the bottom with a rather heavy rod, such as a curtain-rod, which will be horizontal if the wires are exactly equal in length. Opposite the rod, in the same horizontal plane, is a nail or other mark on an adjustable vertical slide. When both wires are heated quickly and as uniformly as possible by passing the Bunsen burner along them, the rod becomes very perceptibly inclined to the horizon, the end nearest the iron wire rising while the end nearest the copper wire descends.

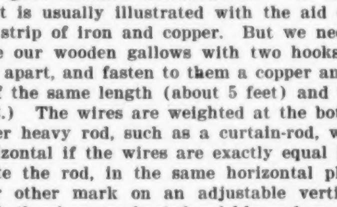

Fig. 4.—Delvalez's Apparatus for Measuring the Expansion of Metals.

M. Delvalez has devised another simple apparatus with the aid of which the expansion of metals by heat can be exhibited, and even measured.

The ends of a metal rod, *T* (Fig. 4), are inserted in two corks, one of which, *A*, is attached to a fixed support, while the other, *B*, is free. The lower surface of this second cork is horizontal and presses on a very small cylinder, *O*, such as a sewing needle, which rests on a cork fastened to the base of the apparatus. As the cork on the free end of the horizontal rod moves in consequence of the expansion of the rod the needle is caused to roll. The extent of its rotation is indicated by a paper arrow, attached to the needle by means of a bit of cork, and moving over a graduated circle, as in the dial pyrometer.

The amount of the elongation of the rod which corresponds to a deflection of 1 deg. on the circle may be determined very simply by rolling the needle between two graduated steel rules, instead of the corks, and noting the distance through which the upper rule must be moved to produce a deflection of a definite number of degrees. The distance divided by the number of degrees gives the elongation corresponding to 1 deg., in millimeters or fractions of an inch, according to the scale used. By moving the rule an exact number of millimeters, or parts of an inch, and reversing the calculation, the deflection corresponding to an elongation of one millimeter or other scale division may be determined.

The rod may be heated as gently as may be desired with a spirit lamp, a candle, or water bath, etc.

With the same apparatus slightly modified, the expansion due to a known rise of temperature may be measured. For this purpose the solid rod is replaced by a metal tube through which steam is caused to flow. In this way the expansion due to heating from the temperature of the surrounding air to that of boiling water is determined very easily.

The same apparatus serves for an exact comparison of the expansions of two different metals for the same rise of temperature.

Let us take, for example, a copper and an iron tube, each about ½ inch in diameter and 20 inches long. One end of each tube is fastened in a vise, while the other moves with considerable friction through a hole in a cork. The two corks are separated by a knitting needle, bearing an arrow which moves over a graduated circle. (Fig. 5.)

A stream of cold water is passed through the lower tube, of iron, and the temperature of the air in the vicinity is taken. Then steam is passed through the copper tube above and when the arrow has come to rest, its position on the dial is observed, while the stream of cold water is still flowing through the iron tube. Knowing the elongation which corresponds to a definite deflection of the arrow, say 50 degrees, we can compute the expansion of the copper tube produced by the heating. By interchanging the connections and repeating the experiment the expansion of the iron tube for the same rise of temperature is determined.

These experiments on expansion are easily made and, though very simple, they are very instructive and convincing. They should, therefore, be of interest to teachers of physics.—Translated for the Scientific American Supplement from Cosmos.

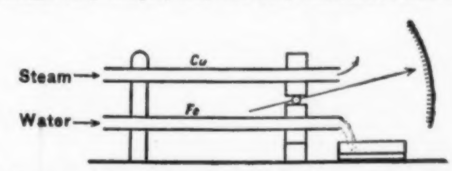

Fig. 5.—Delvalez's Apparatus for Measuring and Comparing the Expansion of Two Metals, for a Given Rise of Temperature.

THE KINETIC THEORY OF GASES.

The kinetic theory of gases at the outset, and as suggested by Herapath (1821), Joule (1851, 1857), Krönig (1856), virtually reaffirmed the classic treatise of Bernoulli (1738). Clausius in 1857-62 gave to the theory a modern aspect in his derivation of Boyle's law in its thermal relations, molecular velocity and of the ratio of translational to total energy. He also introduced the mean free path (1858). Closely after followed Maxwell (1860), adducing the law for the distribution of velocity among molecules, later critically and elaborately examined by Boltzmann (1868-81). Nevertheless, the difficulties relating to the partition of energy have not yet been surmounted. The subject is still under vigorous discussion, as the papers of Burbury (1899) and others testify.

To Maxwell (1860, 1868) is due the specifically kinetic interpretation of viscosity, of diffusion, of heat conduction, subjects which also engaged further attention from Boltzmann (1872-87). Rigorous data for molecular velocity and mean free path have thus become available, and Van der Waals (1873) added a final allowance for the size of the molecules.

Less satisfactory has been the exploration of the character of molecular force for which Maxwell, Boltzmann (1872, etc.), Sutherland (1886, 1893) and others have put forward tentative investigations.

The intrinsic equation of fluids discovered and treated in the great paper of Van der Waals (1873), though partaking of the character of a first approximation, has greatly promoted the co-ordination of most of the known facts. Corresponding states, the thermal coefficients, the vapor pressure relation, the minimum of pressure-volume products, and even molecular diameters are reasonably inferred by Van der Waals from very simple premises. Many of the results have been tested by Amagat (1896).

The data for molecular diameter furnished by the kinetic theory as a whole, viz., the original values of Loschmidt (1865), of Van der Waals (1873) and others, are of the same order of values as Kelvin's estimates (1883) from capillarity and contact electricity. Many converging lines of evidence show that an approximation to the truth has surely been reached.

TRADE NOTES.

Preparation of Wood for the Absorption of Colors.—A process has been introduced in Germany by Herr Joachim von Brenner for increasing the absorbing power of wood fibers for colors or colorants, which are injected for the purpose of dyeing them. It is said to assure to the coloration obtained great resistance to the action of light.

The process consists essentially, after the usual preliminary treatment of the wood by means of superheated steam for separating the cells, in submitting the substance of the cellular walls to the action of sulphuric acid. These walls are chemically modified to such a point that they acquire the property of absorbing the colorants from solutions, and retaining them in the form of fixed compounds, as animal membranes or fibers would do, such as parchment, wool, or silk.

For the practical execution of the process, superheated steam is injected for disaggregating the fibers and softening the incrusting and resinous substances which envelop the parcels of fibers and exert a detrimental influence on the affinity of cellulose for colors. After this treatment with steam, sulphuric acid of 10 to 20 deg. Bé. is injected under pressure. The incrusting and resinous substances, already softened or disaggregated, are then completely destroyed, but on the other hand, the fibers of the cellulose of the wood laid bare are so modified in their surface that in subsequent contact with the colorant, the desired colorations are produced and firmly fixed.

After the fibers of the cellulose have been brought to the state mentioned, the sulphuric acid contained in the mass is neutralized, which may be advantageously accomplished by injecting into the wood any dilute alkaline solution. The salt which may be formed can be removed by treatment with water.

The wood submitted to this treatment is then colored by the injection of the desired colored solution through a cross section. To the solution is added from 5 to 15 per cent of a mordant of any kind, varying according to the composition of the colorant, and consisting, for example, of sulphate of soda, sulphate of iron, acetic acid, chloride of zinc, sulphate of copper, tartar emetic, or a solution of cupric oxide in ammonia.

Methods of Waterproofing Fabrics.—Woolen cloth, writes Siegfried Eisenstein in the Deutsche Färber Zeitung, is soaked in a vat filled with aluminium acetate, of 5 deg. Bé., for twelve hours, then removed, dried, and dried again at a temperature of 60 deg. or 65 deg. C.

Wagon covers, awnings, and sails are saturated with a 7 per cent gelatine solution, at a temperature of 40 deg. C., dried in the air, put through a 4 per cent alum solution, dried again in the air, carried through water, and dried a third time.

Cotton, linen, jute, and hemp fabrics are first thoroughly saturated in a bath of ammonio-cupric sulphate, of 10 deg. Bé., at a temperature of 25 deg. C., then put into a solution of caustic soda, 2 deg. Bé., and dried. They may be made still more impervious to water by substituting a solution of aluminium sulphate for the caustic soda.

White and light-colored fabrics are first put into a bath of aluminium acetate, 4 deg. to 5 deg. Bé., at a temperature of 40 deg. C., the superfluous liquid is removed from the fabric by press-rollers, and it is put into a soap solution (5 kilogrammes of good Marseilles soap in 100 kilogrammes of soft water). Finally it is put through a 2 per cent alum solution, and left to dry for two or three days on racks. The adhering particles of soap are removed by brushing with machinery.

Another method for making cotton fabrics waterproof is as follows: Dissolve 1.5 kilogrammes of gelatine in 50 liters of boiling water, add 1.5 kilogrammes of shavings of tallow grain-soap, and gradually, 2.5 kilogrammes of alum. Let this cool to 50 deg. C., draw the fabric through it, dry and calender.

Cellular tissues are made waterproof by impregnating them with a warm solution of 1 kilogramme of gelatine, 1 kilogramme of glycerine, and 1 kilogramme of tannin, in 12 kilogrammes of wood-vinegar, 12 deg. Bé.

Linen, hemp, jute, cotton, and other fabrics can be given a good odorless waterproof finish by impregnating them with a compound which will be described, and afterward subjecting them to the action of several mechanical brush rollers. By this process the fabric is brushed dry, the fibers are laid smooth, the threads of the warp brought out, and a glossy, odorless, unfading waterproof stuff results. Fabrics manufactured in the usual way from rough and colored yarns are put through a bath of this waterproof finish, whose composition is as follows: 30 kilogrammes of Japanese wax, 22.5 kilogrammes of paraffine, 15 kilogrammes of rosin soap, 35 kilogrammes of starch, and 5 kilogrammes of a 5 per cent alum solution. The first three components are melted in a kettle, the starch and lastly the alum added, and the whole stirred vigorously.

An excellent substance to restore the waterproof properties to fabrics which have lost it consists of a solution of gelatine 0.5 kilogramme and potassium bichromate 0.1 kilogramme, or chrome alum and acetic acid 0.1 kilogramme (to prevent the glue solution from gelatinizing) in 3 to 5 kilogrammes of water. To this solution is added 0.5 kilogramme of ammonio-cupric oxide of 10 deg. Bé. The substance when ready is simply applied to the fabric by means of a brush or similarly, and the texture is then dried and exposed to light.

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